This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

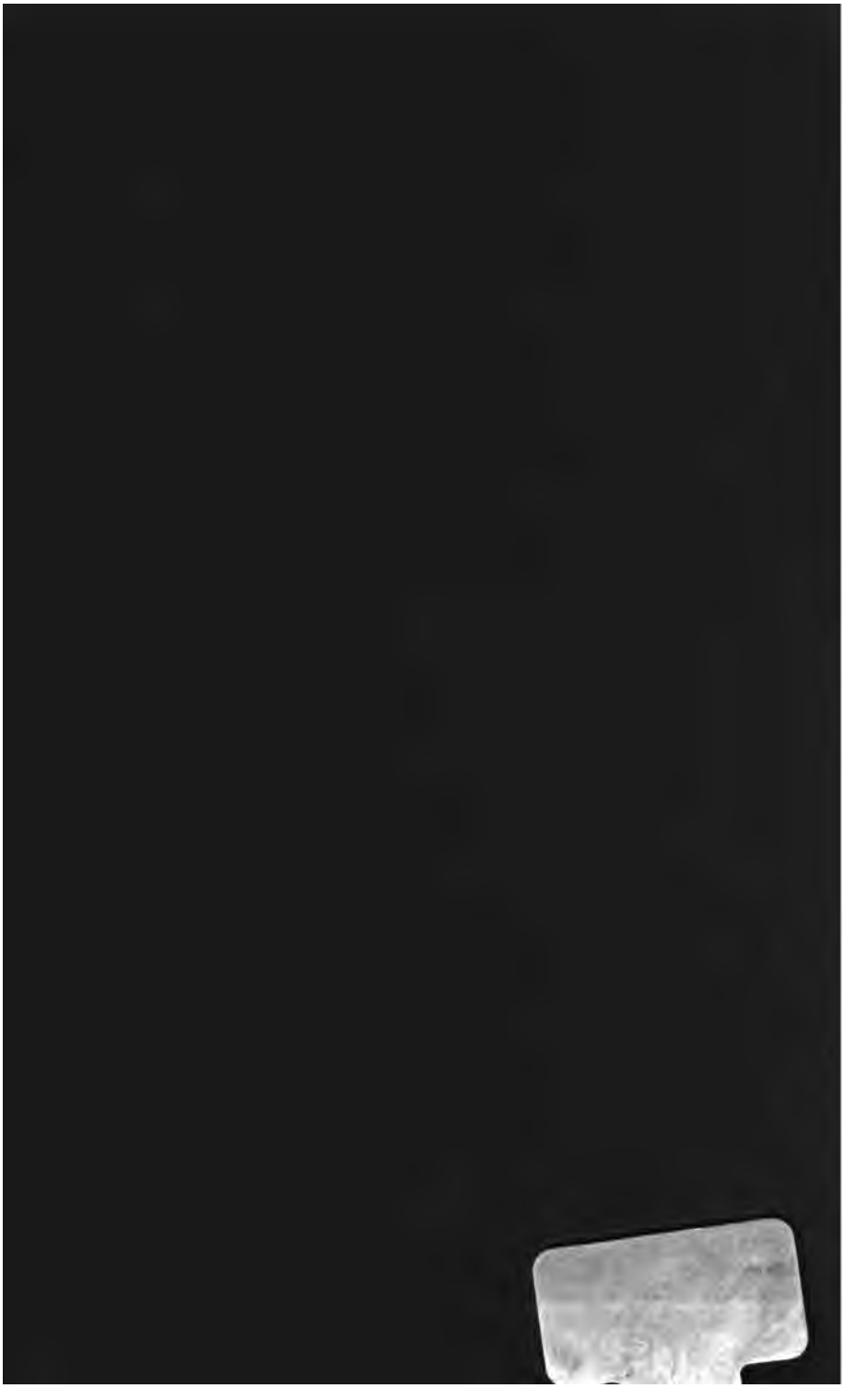
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

THE BATTLE OF THE GAUGES RENEWED 1872.

R. F. FAIRLIE



RAILWAYS

OR

NO RAILWAYS.

RAILWAYS

OR

NO RAILWAYS.

NARROW GAUGE,
ECONOMY
WITH
EFFICIENCY.

v.

BROAD GAUGE,
COSTLINESS
WITH
EXTRAVAGANCE.

By ROBERT F. FAIRLIE.

"The truth appears so naked on my side—
So clear, so shining, and so evident—
That any purblind eye may find it out."
HENRY VI.

LONDON:
EFFINGHAM WILSON, ROYAL EXCHANGE.

1872.

186. e. 54.

LONDON:
GRANT AND CO., PRINTERS, 72—76, TURNMILL STREET, E.C.

To His Grace
THE DUKE OF SUTHERLAND, K.G.,
&c., &c., &c.

My Lord Duke,

I esteem myself singularly fortunate in being permitted to dedicate to Your Grace, as one of the chief promoters of increased facilities for intercommunication, the following effort to extend a knowledge of the principles upon which "Railways of the Future" must eventually be constructed.

I have the honour to remain,
Your Grace's
Humble and obedient Servant,

R. F. FAIRLIE.

TABLE OF CONTENTS.

	PAGE.
INTRODUCTION	7
Summary of advantages claimed for the narrow gauge by General Buell, upon which Mr. Seymour founds his "Review"	13, 14
Mr. Seymour's remarks on the comparative cost of broad and narrow gauge roads up to FORMATION LEVEL, in opposition to General Buell's estimated saving of 23 per cent. for the narrow gauge	16
Demonstration of the fallacy of Mr. Seymour's statements, and corroboration of General Buell's estimate	17—19
Railway progress in Norway—the trial and abandonment of the LIGHT BROAD GAUGE, and adoption of the narrow gauge. Mr. Carl Pihl's development of the narrow gauge, and its great economy in constructive cost, compared with the broad gauge	20
Mr. John Fowler and Mr. John Hawkshaw's comparative estimates of two equally constructed and equipped lines on 5 ft. 6 in. and 3 ft. 6 in. gauges for India	23
Mr. Charles Douglas Fox on "the difference of cost between two (broad and narrow) gauges"	23
The Toronto, Grey, and Bruce Narrow Gauge Railway, Canada	23, 24
Comparison of cost between the Toronto, Grey, and Bruce Railway and an ordinary 5 ft. 6 in. gauge line over the same ground	24, 25
Evidence of the economy of the Denver and Rio Grande Railway 3 ft. gauge as compared with the Kansas Pacific Railway 4 ft. 8½ in. gauge	25
Speech of Mr. Carl Pihl in Canada, at the opening of the Toronto, Grey, and Bruce Railway, on the advantages of the narrow gauge	25, 26

PAGE.

Mr. Seymour's mistake in including shops, stations, &c., as part of the cost of road-bed up to the formation level 27

Mr. Seymour's argument against General Buell's second and fourth claims for economy in the superstructure and rolling stock 27

Demonstrating the incorrectness of these views, with particulars of the cost of superstructure, showing General Buell's estimated saving to be correct..... 27—29

Showing the fallacy of the claims usually made in favour of light broad gauge lines worked with two ordinary engines coupled back to back, in substitution for efficient narrow gauge worked by Fairlie engines 31, 32

Mr. Fowler's tabulated estimates for two equally constructed and equipped lines, on 5 ft. 6 in. and 3 ft. 6 in. gauges, between Kotree and Moultan, India ..... 32—34

Cost of transferring goods from narrow to broad gauge lines 35, 64, 65, 114

Progress of narrow gauge in America 36

Weight of rails governed by the weight on driving wheels of locomotives 37

Extraordinary advantages which would accrue from the employment of Fairlie engines in working the enormous coal traffic to London 37

Demonstration of the fact that locomotive engines, weight for weight, are more powerful on the narrow than on the broad gauge 38

Width of gauge limits the power of ordinary locomotives, whilst gauge in no way controls the power of Fairlie engines..... 39, 40

Mr. Seymour illustrates his view of the only difference in cost which can be claimed for the narrow against broad gauge rolling stock 40

The fallacy of this view proved..... 40, 41

Paying and non-paying weight of freight trains in America 41

Fallacy of the statement that if narrow gauge is adopted the length of trains must of necessity be increased..... 42

Paying and non-paying weight of passenger, goods, and mineral trains in the United Kingdom 42

Paying and non-paying weight of passenger, goods, and mineral trains in France 42, 43

Proportion of width of cars to the gauge of railway, and of length of wheel base of each vehicle to gauge, at the same time securing steadiness in running 44, 50

PAGE.

Letter from Mr. J. Slater, of the Gloucester Wagon Company, proving a saving of FIFTY PER CENT. in the cost of maintenance of narrow gauge (4 ft. 8½ in.) stock compared with broad gauge (7 ft.) stock of equal capacity; showing also that the capacity of the narrow gauge is equal to the broad 47, 48

Speed attainable with safety on the narrow gauge 48, 49

Demonstrating the absurdity of Mr. Seymour's statement that the cost of locomotives, provided the same amount of power is used, will be no greater for the wide than the narrow gauge 49

General Buell's last claim for economy between the paying and non-paying weight on broad and narrow gauge lines. The ingenuity displayed in building in India and our Colonies 5 ft. 6 in. gauge roads, and running on them stock the same width (or capacity) as now used on the 4 ft. 8½ in. gauge roads. What becomes of the necessity for the extra width of gauge? 50

Demonstrating by existing practice the great economy in dead weight alone of narrow against broad gauge lines ..... 51—57

French traffic statistics for 1868 57

Taking French practice as a basis, showing how much dead weight is reduced in carrying 127,598 tons on the narrow compared to broad gauges, and the saving of £787,500 in one year on six French lines 57

Mr. Seymour's further illustrations of his views in favour of broad gauge ..... 58—62

Advantages claimed by Mr. Seymour by adopting narrow gauge stock on broad gauge roads, and the demonstrations he gives of the fallacy of his own reasoning 63

Mr. Seymour an advocate for break of gauge. Gen. McCallum's demonstration that break of gauge, under certain conditions, is a great advantage 63, 64

Cost of transferring freight from one gauge to another on different railways 65

Comparison of frictional resistance of wheels of different diameters and gauges—results of experiments of MM. Vuillemin, Guébhard, Dieudonné, and Wood ..... 65—68

Third, fourth, and fifth advantages claimed by Mr. Seymour for placing narrow gauge stock on broad gauge lines 68, 69

The fallacy of these supposed advantages summarised 69, 70

Angles of stability. American and Norwegian stock 70

PAGE.

Influence of curves on different gauges in the resistances of trains 72—75
Mr. Seymour's intelligent teamster showing what he really would do were he driven to work traffic in the proportion it is now done 78, 79
General McCallum's report as to work done by locomotives on the New York and Erie Railroads 82
Mr. H. S. Goodwin's report respecting work done by locomotives on the Lehigh Valley Railway 82, 83
Mr. Seymour's reasons for recommending a 5 ft. gauge for the Union Pacific, and a 4 ft. 8½ in. gauge for the Texas Pacific Railways 85, 86
Description of the Festiniog Railway, its rolling stock and cost of working ..... 87—105
M. Nördling's and Baron von Weber's report of experiments on the Orléans Central Railway ..... 105—108
Construction of narrow gauge railways justified where lengths exceed three miles 109
Tabular statistics of three narrow gauge lines 110
Report of Mr. D. P. Sullivan to the Austrian Minister of Public Works on the Fairlie system 111
Report of M. von Nördling to the Austrian Minister of Public Works on the Fairlie system 112
Signor Biglia's (of the Italian Public Works Department) report on narrow gauge railways 113
Photographs of Fairlie 3 ft. 6 in. gauge carriage stock built for the Dunedin and Port Chalmers Railway, New Zealand. . *facing* 116
Summary of advantages of 3 ft. and 3 ft. 6 in. gauge railways .. 117
Photographs of Fairlie 3 ft. 6 in. gauge wagon stock, built for the Dunedin and Port Chalmers Railway, New Zealand. . *facing* 118
Summary of advantages claimed for the Fairlie engine 119
Photograph of Fairlie engines built for the Dunedin and Port Chalmers Railway, New Zealand, 3 ft. 6 in. gauge .. *facing* 120
Photograph of Fairlie engines built for the Mexican Railway, 4 ft. 8½ in. gauge ..... *facing* 120
Photograph of Fairlie engines built for the Patillos Railway, Peru, 2 ft. 6 in. gauge ..... *facing* 122
Photograph of Fairlie express mail engine for the Grand Russian Railway, 5 ft. gauge ..... *facing* 122
Denver and Rio Grande Railway, report on, by Mr. S. Bowles .. 124
Reply to Mr. Ramsbottom's report against the principle of the Fairlie engine. *Illustrated* 134
Paying load and dead weight diagrams 143

INTRODUCTION.

THE rapidity with which railways on a narrower gauge than that of 4 ft. 8½ in. are now being constructed in the United States, and in other parts of the world, is regarded with many misgivings by a large number of engineers, who imagine that they see in this departure from an orthodox practice, the establishment of a system that shall be of comparatively little service, that will entail loss, direct and indirect, and that the progress of civilisation and the development of wealth which the construction of railways has hitherto so vastly promoted, will be retarded if not stayed where lines of 3 ft. or 3 ft. 6 in. shall supersede those broader roads in the belief of which they have been educated. In short, engineers of this class maintain that because a width of 4 ft. 8½ in. has been hitherto made the standard, that therefore a reduction of this width can only give efficiency diminished in proportion as the rails approach each other, while the actual outlay for first construction is but slightly affected, and the subsequent cost of

working and of maintenance remain unaltered. It is only a short time since Mr. Hawksley, the President of the Institution of Civil Engineers, remarked in the course of an address delivered on the occasion of his election to the presidential chair (the highest professional honour the Institution can bestow), that a new gauge of absurd dimensions (3 ft. $3\frac{3}{8}$ in.) had been introduced into India, at the instance of some unknown crotchety person, to inflict upon the country all the evils of break of gauge, and all the inconveniences of an inefficient railway accommodation, when there already existed a magnificent railway system which, when completed, would fulfil every requirement.

Unfortunately for India, her railways have been made too magnificent, and the comparatively short mileage now constructed has been built at a stupendous outlay, to accommodate a very small traffic. And this same remark holds good in Australia, where the advocates of broad gauge are straining every effort to extend the ruinous system with which the country is already burdened. But in England authoritative opinion against the introduction of the narrow gauge and its necessary adjuncts is not so much expressed as implied; argument gives place to action, powerful in check-

ing true railway progress, and other motives are too often apparent in the course taken to achieve this end.

In the United States, on the other hand, the case is widely different: opinion finds free vent among the members of the profession, and with the greatest earnestness, and with much ability, the merits of both sides of the case have been universally discussed; while thousands of miles of narrow gauge line have been commenced, which when completed will practically and thoroughly decide the now much-vexed question. To this characteristic energy (it is scarcely two years since I had the pleasure of advising upon the details of the first great narrow gauge railway with the directors of the undertaking) the world will owe a debt of gratitude, and the great problem of railway progress will have been solved years earlier than if it had been left in the hands of the more prejudiced and less progressive engineers of this country.

Interested as I am in the matter of narrow gauge railways, for I have during many years devoted my best energies—with no small success—to proving the numerous and great advantages to be derived from their adoption, I gladly take

advantage of the opportunity afforded me in the document recently published by the Hon. Silas Seymour, of New York, upon the question of Narrow Gauge Railways, in answer to a report prepared by General G. P. Buell, Chief Engineer of the Texas Pacific Railroad, in which he advocated the adoption of a 3 ft. 6 in. gauge. This report was submitted by Marshall O. Roberts, Esq., President of this Railroad, to Mr. Seymour for an opinion, as the Board of Directors did not feel justified in assuming, unadvised, the responsibility of adopting a narrow gauge for a great trunk line 1,500 miles in length.

In his reply Mr. Seymour has taken much pains to prove the fallacy of the arguments in favour of narrow gauge, and is apparently desirous of treating the subject with the utmost justice; but, unfortunately, he has not taken the trouble to make himself acquainted with existing experience, and treats the whole question theoretically. Had he made use of information lying ready to his hand, it is probable that his pamphlet would never have been written; certainly it would have been vastly modified, and he would have been enabled to touch the vital points of the question, which he has now failed to do.

But as his "Review" may be regarded as representative, expressing the opinions of narrow gauge antagonists, I have thought it well to analyse, paragraph by paragraph, the whole of Mr. Seymour's arguments, and to prevent any confusion, I have quoted them in their proper order, and appended my own comments.

With these few remarks, then, I place my reply to Mr. Seymour's "Review" before the public, who must judge the case, and I beg them to bear in mind the following extract which I have borrowed from the appendix to his pamphlet, so true and just it is, so *apropos* to the matter under discussion :—"The question to be decided, therefore, in determining the proper width of gauge to be adopted on any given line of railway, is not whether a gauge of 6 ft. possesses greater capacity than a gauge of 4 ft. 8½ in., but rather *what width of gauge is the best adapted to admit of such a construction of machinery as will more profitably overcome the resistance of the line, and that will meet the nature and extent of traffic, present and prospective.*"

ROBERT F. FAIRLIE.

Victoria Street, Westminster, London, S.W.
April, 1872.

THE

TRUE PRACTICE OF NARROW GAUGE.

In the absence of General Buell's Report, which I regret that I have not seen, I cannot do better than quote Mr. Seymour's summary of it, together with the chief advantages he claims for a narrow gauge railway. "I have read" (in paragraphs 1 to 6), he says, "the Report of your Chief Engineer, General G. P. Buell, in which he recommends you to adopt a gauge of 3 ft. 6 in. in preference to that of 4 ft. 8½ in., or the 3 ft. gauge, for the Texas Pacific Railroad, extending from the Mississippi Valley to the Pacific Ocean, a distance of 1,500 miles.

"The confidence and earnestness with which your Chief Engineer presents his views, and urges the recommendations upon this important subject, show, beyond a doubt, that he is entirely honest in his convictions; and they are therefore entitled to full and fair consideration.

"He admits in his Report that your road will necessarily come into competition with two other great trunk lines to the Pacific; and he claims that it already has advantage of the other route in climate, distance, and economy of construction. He also claims that the whole subject hinges on the three points—speed (which is time), capacity, and economy; and that these three points are secured by the adoption of a gauge 1 ft. 2½ in. narrower than the gauge of the other two grand competing lines, and which has been in general and successful

use throughout the civilised world during the past half-century.

" The five following reasons are given for recommending the 3 ft. 6 in. gauge in preference to the one of 4 ft. 8½ in. :—

" 1. That in the construction of the road-bed, &c., the difference will be 30 per cent. of cost of narrow gauge.

" 2. That in the construction of the superstructure the difference will be 45 per cent. of cost of narrow gauge.

" 3. That with proper construction of rolling stock, a speed of 35 to 45 miles an hour can be attained with perfect safety.

" 4. That in the construction of rolling stock the difference will be 50 to 55 per cent. of cost of narrow gauge.

" 5. That in the loaded train of mixed freights and cars on the 3 ft. 6 in. gauge, the percentage of dead weight to load will be about $\frac{47}{100}$; while in the similar train on the broad gauge road the percentage of dead weight to load is about $\frac{75}{100}$."

The Report thus summarised, Mr. Seymour proceeds as follows :—

> *Paragraph 7 of Mr. Seymour's "Review."*—"I cannot concur with your Chief Engineer, either in the premises which he assumes, or in the conclusion at which he arrives. Although I will admit that, assuming everything else to be only equal, if either one of the reasons which he gives can be satisfactorily proven true, he will have gained his case."

In this paragraph, Mr. Seymour shows that he is "honest in his convictions," and he gives proof of a full desire to deal with the whole subject in an unprejudiced way, and to view it fairly according to his lights. Nay, more, he indicates how much he has railway interest really at heart when he says that General Buell will have gained his case, should he be able to prove either of his claims in favour of the narrow gauge. This is indeed the true spirit of a just antagonist, and I trust that the time may soon arrive when Mr. Seymour shall become a warm

advocate of a system he admits to be the right one if it comprises the three requirements of safety, efficiency, and economy.

> *Paragraphs* 8 to 10.—"The great difficulty, however, will be found to rest in obtaining this satisfactory proof. Take, for example, the construction of the road-bed. I should want to see two parallel lines of equal length, and running over precisely similar ground, constructed, one for the wide, and the other for the narrow gauge, having equal margins for right of way, drainage, slopes, bermes, &c., and then the difference of cost could be correctly ascertained. But in the absence of such a test, I cannot admit that there is anything like the difference claimed for this one item, in favour of the narrow gauge."
>
> "But as this test never has, and probably never will be made, it only remains to show, by *indirect* or *negative* demonstration, that the proposition cannot be true."
>
> "If I understand the proposition (which is stated somewhat ingeniously), it is, that if the narrow gauge road-bed costs 10,000 dols. per mile, the wide one will cost 13,000 dols., the difference being $\frac{3}{13}$, or about 23 per cent."

In justice to Mr. Seymour, I should regret to assume for a moment that he desires the statement in the eighth paragraph to be taken otherwise than in a figurative sense; he can hardly wish it to be believed that he would require to see two railways of different gauges *constructed* over the same ground before he could ascertain the difference in cost of each. An engineer of his standing must be accustomed to make estimates, and could easily ascertain this difference of cost for himself. What would be thought of any one who would state—supposing that he were applied to for an opinion upon the relative cost of different designs for a bridge to span a given opening—that he would require to see the designs constructed and erected before he would admit the difference of cost between them? It is the business of the engineer to ascertain such details to a nicety, and they can be found exactly. To suppose, therefore, that Mr. Seymour wished to convey the absolute meaning of this

paragraph would be to infer that he is devoid of all knowledge of his professed business, and any further argument would be thrown away upon him.

As he says, "such a test never has, and probably never will be made;" it remains, therefore, to show, by *direct* and *positive* demonstration, that his assertions on this point are not true.

It is scarcely fair on the part of Mr. Seymour that he has only stated General Buell's conclusions without also giving some of the details by which those conclusions were arrived at; as, however, he has excluded any mention of these from his "Review," I will endeavour to check the results which the General has submitted, by the experience already obtained in practice, and the opinions of some of our leading engineers based on that experience.

And first as to General Buell's estimated reduction of cost of road-bed for the narrow gauge of 23 per cent., Mr. Seymour says:—

> *Paragraphs* 11, 12, 13.—"Perhaps I cannot illustrate my idea of the error better than by assuming an average mile of grading, masonry, &c., to be fully completed, and ready for the superstructure of the wide gauge; and then, by assuming that a longitudinal section, extending the entire length, and one foot two and a half inches in width, be taken out of the centre, and the sides brought together, so as to close the vacant space. We should then have a perfect road-bed for the narrow gauge; and the question to be determined would be the relation which the longitudinal section so taken out bears to the road-bed as left complete for the narrow gauge."
>
> "The side slopes of excavations and embankments, which often contain more material than the prism, would, of course, remain the same. The side drains, bermes, and the wings, end walls, and copings of culverts, would also remain the same. If truss bridging occurs, the entire masonry and superstructure of this would remain the same for both gauges, for the reason that the width of bridges required for passing cars of the widest gauge has been found none too great to allow of the requisite lateral bracing to keep the bridge in perfect line and adjustment."

"The road-bed for the wide gauge is generally 14 ft. in width at grade, but I assume that 12 ft. in good material is quite ample. By taking out the longitudinal section referred to, there would remain 10 ft. 9½ in. for the narrow gauge bed: but reducing this width to 10 ft., which I presume would be considered as equally ample, and the actual saving in the prism would be only one-sixth, or about 16 per cent. When we add to this reduced prism the cost of the other elements, which remain the same in both cases, and consider that the shops, station-houses, platforms, &c., &c., would also remain substantially the same, the actual percentage of saving in total cost would become so small, as compared with the amount claimed by your engineer, that his first reason for recommending the adoption of the narrow gauge loses nearly its entire force."

In the eleventh paragraph—the first in which Mr. Seymour approaches argument—the fact that he has failed to grasp the true narrow gauge practice is clearly manifest. He regards the question from a point of view common to all those who take up the subject for the first time, or who regard narrow gauge at the best as a temporary makeshift, not as an efficient substitute for the broad gauge. He imagines that a railway of 3 ft. 6 in. in width, as compared with one 4 ft. 8½ in. wide, is reduced in efficiency, as the width apart of the rails is diminished, whilst the cost remains almost the same; and, as a natural consequence of a very imperfect knowledge of the subject, he loses sight of the great advantages of narrow gauge—its efficiency and economy in working—and considers as most important the economy in construction. Now, although this economy in construction is a matter of vast importance in all cases, and of vital moment in many—for there are hundreds of thousands of miles of country waiting to be developed, but wanting the means to build and to work broad gauge roads—though this saving of first cost is so large, it is rather an incidental than a fundamental advantage. The experience of railway engineers "during the last half-century" has given to the world a system of railways for the most part 4 ft. 8½ in. gauge, and built with

certain widths of formation, and gradients, bridges, viaducts, and tunnels, all proportioned to the width of track, and these roads are built for rolling stock which must be unduly heavy for the very partial loads they are compelled by the exigencies of traffic to convey; for the best practice proves that a mixed freight on lines doing the heaviest business can only be conveyed with a vast extravagance in hauling power, due to the grand disproportion necessarily existing between the vehicles and the available loads they are made to carry. And this condition of things, inseparable from railroads of 4 ft. 8½ in. gauge and upwards, entails all the extra cost due not only to construction, but to rolling stock, maintenance, power required for haulage, and to the renewals of the permanent way. Further on, I shall propose to enter into the question of rolling stock, at present I mention it incidentally to show that the primary error in orthodox railway construction—that of excessive size of vehicles—is carried of necessity down to the road upon which they run.

That very many railways built after this fashion are profitable in their working, is no proof that the same lines built upon the true principles of economy would not have been more profitable, any more than the experience of "half a century" has left nothing to be desired in railway construction. Indeed, this experience has led some few, and will soon conduct all, to the conviction that a complete railway reform is required—that of narrow gauge—and if we investigate the matter closely, we shall see that as we descend from the outrageously broad gauge of our own Great Western, we approach more nearly to true economy, until leaving behind the empirical 4 ft. 8½ in., we reach a point where the maximum of advantage, combined with a minimum of cost, culminates.

Even regarded as Mr. Seymour wishes narrow gauge to be regarded, as broad gauge on a reduced scale, his reasoning in paragraph eleven is erroneous, for while to make the former he

cuts out a prism 1 ft. 2½ in. wide in the middle of the track of the latter, he forgets that with the narrow gauge it is possible to reduce materially the heights of embankments or the depth of cuttings in due proportion; nor does he make any allowance for works on side-lying ground. I grant that if he assumes the same gradients, and only 2 ft. reduction in formation width, the saving obtained would be but 16 per cent. of the prism, but this assumption is a false one. *An average mile of properly designed narrow gauge road, ready for grading, is not an average mile of standard road, with a piece cut out of the centre.*

The true narrow gauge practice permits a closer adaptation of grade to the natural surface than is attained (I speak of a railway practice as the "half-century's" experience has made it) on the broad gauge, hence lower-banks and shallower cuttings, least felt on horizontal, and most on side-lying ground. It involves a great reduction of formation width, because the running weights are less, and require less supporting area. By the facility it possesses of employing sharper curves, in difficult country, heavy works are reduced in cost, and tunnels are for the most part avoided, or where they are absolutely necessary, the labour in making them is less. So with bridges and viaducts, and in fact with all the works coming under the head upon which a saving of 23 per cent. is claimed by General Buell. And although Mr. Seymour may wish to prove, by cutting down the construction expenses, that the cost of the broad gauge is but little in excess of that of the narrow, it will be seen that he can effect this only with the result of a miserably built road, which shall cost more in maintenance than is saved in construction, and which shall be inefficient into the bargain, whilst on the other hand, the cheap narrow gauge line will be more capable of serving the traffic profitably than the best broad gauge he could lay down.

In the absence of the data upon which General Buell founds his conclusions as to cost, I am not in a position to criticise

his detailed estimates for the Texas Pacific Railroad; if I were, I venture to believe that I should find that he has in no way under-estimated the expenses. It must suffice, therefore, to show that his alleged "difference of 30 per cent. of narrow gauge," or, as Mr. Seymour puts it, 23 per cent. on the cost of the broad gauge, for works up to formation level, is not excessive, but compares favourably with the experience available in narrow gauge railway construction, and of which Mr. Seymour is unfortunately ignorant.

As the earliest and most important examples of successful narrow gauge construction, I may refer to the Norwegian system introduced since 1861 by Mr. Carl Pihl, and now being extended as fast as the means of the country are available. The first railways in Norway were built by Mr. Robert Stephenson about 1854, on a 4 ft. 8½ in. gauge, and at a cost of more than £11,000 a mile. It was clear that the traffic to be obtained could never pay for such an outlay, and Norway was in a position in which many countries stand to-day—she had to choose between cheap railways or none. Naturally, she chose the former alternative, and her able government engineer, Mr. Carl Pihl, devoted himself to the construction of the least expensive lines possible upon the standard gauge. In this he succeeded so far as to reduce the cost to £6,350 a mile, including stations and rolling stock, *but no workshops*. This was a great advance, but again the same alternative stood before the government, and this time Mr. Pihl resolved upon the radical reform which has rendered railway extension possible through districts where distances are great and traffic small. He resolved upon adopting the same gauge which General Buell has recommended to his directors, and succeeded in cutting down the cost per mile for one line to £3,142, for another to £5,300, and for a third to £4,600, including rolling stock, stations, *and workshops*, and taking his line through most difficult country, over which a large amount of rock cutting,

tunnelling, and bridging occurred, some of the viaducts being over 70 ft. in height and of great length. And it must be remembered that this reduction in cost was effected without the adoption of very sharp curves, for although "the greater facility of traversing sharp curves is a decided and no small advantage to be gained by the use of the small gauge" (I quote Mr. Pihl), this advantage was not made use of in the early Norwegian lines, though I believe some of the later ones are built with curves of very small radius. I have no doubt that Mr. Seymour may answer to these comparative figures that the nature of the ground may have been more favourable for the smaller gauge, but we have Mr. Pihl's statement that this was not the case. And I may advantageously quote this gentleman's deductions of absolute difference of cost between the two systems. He finds that the average difference in height of cutting and bank on the 4 ft. 8½ in. gauge, as compared with 3 ft. 6 in., is as 13 to 10, and taking the example of an embankment 50 ft. in height with slopes of 1 to 1, the proportions of earthwork in the two systems stand as 7 to 4, and not as about 32 to 31, as Mr. Seymour would make out in a parallel case. But General Buell doubtless made allowance for greater slopes than 1 to 1, in which case the difference would be less than in the case taken for illustration. Probably in deference to the standard railway practice, Mr. Pihl adopted for his formation width 12 ft. 6 in., a dimension which subsequent experience has shown to be excessive. And though Mr. Seymour considers that 10 ft. may be enough, I prefer to take the more reasonable width of 3 times the gauge, or 10 ft. 6 in., which is ample, and which was recommended by Mr. John Fowler in his report to the Indian Government. But I cannot for a moment admit Mr. Seymour's assumption that 12 ft. would be found sufficient for the formation width of a 4 ft. 8½ in. gauge. Of course he *could* build his line upon such a formation, but he would find that the maintenance expenses would far more than counter-

balance the saving in first cost; and as I am supposing an efficient line to be the object sought, I can allow of no less width than 14 ft., and I am sure no experienced engineer will differ from me on this point. We have then a formation width of 14 ft. compared to 10 ft. 6 in., and an average height in bank of 13 ft. as compared with 10 ft., taking the Norwegian conditions as a standard. If we assume slopes of 1½ to 1, the areas of such banks as I have supposed will be 435 ft. and 255 ft. respectively, whilst Mr. Seymour's bank, with 12 ft. formation, would contain 409 ft. The contents of the 3 ft. 6 in. bank would be but 58·6 per cent. of the 4 ft. 8½ in. bank, or 62 per cent. of Mr. Seymour's embankment, which latter would contain 94 per cent. of the properly designed earthwork on the broad gauge. If we suppose that the works upon the line do not average so great a height as mentioned above, and assume them to be only 4 ft. on the average for the broad, and 3 ft. on the narrow gauge, we shall still find the difference to be 44 per cent. in favour of the latter. The foregoing remarks hold good in the case of cuttings, and in an equally marked degree; the narrow gauge permitting of a nearer surface grade, the allowance for side drains need not be so large. In rock cuttings and tunnels, the difference is of course less, because the formation width of the broad gauges can be reduced considerably in passing through such works.

With the reduction in the height of cutting and bank would follow a proportionate saving in the material required for culverts, and a reduction would be also effected in the bridges. How great could be the economy on this item, depends of course on the nature of the country over which the line passes; it is certain that the heights of the bridges and viaducts would be considerably decreased, for the same reason that the earthwork is reduced, and the smaller width would affect also the weight of the roadway, 25 per cent. being cut out of the width of the superstructure. The main girders may be made lighter,

and these would still further be lightened, because the total passing load per foot run would diminish with the gauge. Mr. Seymour's assumption that the width cannot be reduced on account of the loss in lateral stiffness, is not correct, except in those occasional circumstances wherever very long spans are a necessity. If it were so Mr. Pihl's light and narrow viaducts 70 ft. in height ought to have fallen long since; but they stand, to refute Mr. Seymour's argument. But while it is impossible to arrive at an exact conclusion upon the question of bridges without exact data, I may mention that Mr. John Fowler in advising the Government of India to adopt a 3 ft. 6 in. gauge, estimated the saving in the cost of construction at 10 per cent. as compared with the bridges necessary for a 5 ft. 6 in. line, and Mr. John Hawkshaw, although an opponent to narrow gauge, assumed a greater saving. The estimates of these two gentlemen were prepared with great minuteness, and were based on the actual quantities of a given road. But facts are not wanting on this, nor indeed on any point connected with the saving in building narrow gauge lines. Mr. Charles Douglas Fox has had a large experience on the subject. He says:— "The difference in cost between the two gauges is made up chiefly of the items of earthwork, bridges, culverts, ballast, and sleepers, and in the first and most important item, a large saving is effected by the use of sharper curves than would be advisable on a wider gauge." This remark was made in reference to the Toronto, Grey, and Bruce Railway of Canada, built by Mr. Fox on the 3 ft. 6 in. gauge, and his experience is interesting because it bears out that of Mr. Pihl, and shows that General Buell is probably quite within the mark when he claims a difference of 23 per cent. in favour of narrow gauge. Thus, Mr. Fox says also in reference to the Toronto, Grey, and Bruce, "Whereas a 3 ft. 6 in. line would cost 15,000 dols. per mile, a 5 ft. 6 in. line, sufficiently strong to take the rolling stock of the main lines, would cost 23,000 dols., but I believe

a broad gauge line of similar construction and equipment to the narrow gauge line proposed could be constructed for 20,000 dols. per mile. That this estimate of the comparative cost is correct is evident, first, from the results of actual surveys made by the company, of a considerable portion of the line upon which the detailed comparative estimates were based; second, from the experience of ourselves and others as to the cost of lines of different gauges in Norway, Sweden, India, South America, and Australia; and it is further thoroughly confirmed by the estimates given by Mr. Reid and Mr. Shanly for a railway of the 5 ft. 6 in. gauge from Guelph to Mount Forest. This line, over an almost perfectly level country, and almost entirely without bridges, as I can testify from personal inspection, without rolling stock, and, as Mr. Shanly described it, "of flimsy construction," is estimated at 15,500 dols. per mile. Add to this the same allowance for rolling stock which has been taken for narrow gauge, namely, 2,000 dols. per mile, and there are only 2,500 dols. left per mile, out of my price of 20,000 dols. to provide for the considerable difference in the earthwork and bridging upon the other route, and for making the construction substantial, though light, instead of "flimsy." Again, "Of one thing I am convinced, that if the railways in question are carried as in accordance with my recommendations, they will be found to answer fully all the requirements of the district, and to effect such economy of construction, combined with really excellent materials, as never could be obtained in the broader gauge." These remarks, made by Mr. Charles D. Fox in 1868, have been fully substantiated by subsequent results. Let me compare the Toronto, Grey, and Bruce 3 ft. 6 in. line, which cost 13,000 dols. per mile, without rolling stock, with an ordinary 5 ft. 6 in. line over the same route, which would have cost 21,000 dols. Assuming that the cost of a 4 ft. 8½ in. line over the same ground would have decreased in proportion to the gauge, such a road would have cost

17,800 dols. per mile against 13,000 dols., showing a saving of 27 per cent. on the finished line. The ballast, permanent way, &c., would be rather more than that of the works up to grade, and would reduce the saving to 25 per cent., which is more than Gen. Buell has claimed that he can do on the Texas Pacific Railroad.

More recent evidence bearing directly upon this point of economy is afforded by the engineers of the Denver and Rio Grande 3 ft. gauge railway, running from Denver, in Colorado, to the city of Mexico, and now being rapidly built. Except in the mountain districts, this line is being completed for 14,000 dols. per mile, including stations, engine and carriage buildings, workshops, and snow sheds; whilst the Kansas Pacific Road, 4 ft. 8½ in. gauge, laid out by the same engineers, and built by the same contractors, through exactly similar country, cost 22,000 dols. per mile, showing a saving of 8,000 dols. per mile, or more than 36 per cent.

On the occasion of the opening of the Canadian light railways last summer, Mr. Pihl made a visit to America, and in the course of a speech during the ceremonial he stated that he "was led to adopt this gauge rather than a narrower one, or the usual gauge of 4 ft. 8½ in., from the result of close calculation, which satisfied me that on it can be combined a maximum of capacity, comfort, efficiency, and safety with the minimum of construction and working expenses. If, on the other hand, the gauge is reduced to 3 ft. or less, stability, comfort, and economy are sacrificed, while with the 4 ft. 8½ in. or greater gauge, expenses are multiplied in many departments without corresponding increase of useful effect. It must not be supposed, however, that economy depends wholly on the gauge. But rather that it is the basis on which to proportion the various works and carriages necessary to carry the required amount of traffic. Thus, by adjusting the size of the locomotive in such a manner that you get, for example, a pressure on each driving wheel of not more than 3 or 3½ tons, you are enabled to use lighter

embankments, bridges, and rails, and decrease the expense of repairs in these important elements in the cost of a railway. I am often asked the exact difference between the cost of a railway on a gauge of 3 ft. 6 in. and 4 ft. 8½ in. It is difficult to make definite comparison, as every railway is different. *I believe, however, that it may be stated generally that the narrower gauge can be built for say one-third less.* In working I can give a better test by supposing a mixed train with three passenger coaches with places for 96 passengers, but containing only 60 people, and 14 goods wagons on a line with a ruling gradient of 1 in 100. In Norway the narrow gauge passenger coaches weigh 4·1 tons, goods wagons 3·3 tons, locomotives 16 tons. Estimating each passenger at 140 lb., and the load of freight at 70 tons, there is in all 148½ tons. On the 4 ft. 8½ in. gauge, the three passenger coaches weigh 6·4 tons each, and freight cars 4·3 tons, and engine 20 tons; adding the same amount of freight and passengers, the sum is 173¼ tons, or 18 per cent. saved in locomotive power on the narrow gauge. Should the comparison be made with existing styles of carriages on 4 ft. 8½ in. and 3 ft. 6 in. railways in this country, the result would be much more favourable to the narrow gauge."

Were it worth while I could quote the experience obtained upon the subject in Russia, Sweden, Australia, India, New Zealand, and South America; but I think I have said enough upon this point, and may now dismiss it, with a passing reference to the Count Bobrinsky, whose energy and skill, ably assisted by Professor Saloff, have introduced railway reform into Russia, where the Livny railway has been built, at a cost of 40 per cent. less than a broad gauge would have cost over the same ground.

Surely my assertion has been justified, that if Mr. Seymour had been acquainted with the barest facts connected with the subject he has taken in hand to discuss, his "Review" would never have been written, or would at all events have received important modification.

I do not understand how Mr. Seymour can include the cost of shops, stations, platforms, &c., in the expenses up to grade level. These items are independent of the cost of any line; they must therefore be separated. Excessive amounts may be expended on the station works of a 3 ft. 6 in. line, and mere sheds may be made to do service on the wider gauge, the difference in cost of which would go far to reduce the per-centage of saving. It is evident, therefore, that this element cannot be introduced, excepting so far as this, that a narrower gauge requires less width of buildings, and that—the structures being similar—the expense of building them would be less:

> *Paragraphs* 14, 15, 16.—"By the same process of reasoning, the second and fourth reasons given by him, in which he claims that 45 per cent. will be saved in cost of superstructure, and from 50 to 55 per cent. in cost of rolling stock, may be shown to be equally erroneous."
>
> "The saving in cost of superstructure, the weight of rails remaining the same, will be only the value of a section 1 ft. 2½ in. in length, cut from the centre of each tie."
>
> "The requisite weight of iron rails is generally supposed to be governed by the weight resting upon each driver of the engine; and as this weight creates the adhesion, and therefore governs the power, it follows that, with the same weight of train, it must be equal upon both gauges. If it is claimed that the same amount of tonnage can be hauled with greater economy, by multiplying trains, and using lighter engines, then I maintain that the same principles can be applied upon the wider gauge with equal economy, and, therefore, that no greater weight of rail is required."

It is scarcely fair towards General Buell, that Mr. Seymour states the saving claimed for the superstructure of the 3 ft. 6 in. is 45 per cent. The General says that the difference will be 45 per cent. *of the cost of narrow gauge*—in other words, that the actual saving would be about 32 per cent. "By the same process of reasoning" as I have previously used I may show that this amount is not much if at all excessive. There exist

three elements of economy under this head; 1st, the rails; 2nd, the ties; 3rd, the ballast. The weight of rails for a 3 ft. 6 in. line, as efficient as a 4 ft. 8½ in. line, may be considerably less, and in this is to be found the greatest item of saving. Mr. Seymour very truly says that the weight of the rails is governed by the maximum weight per engine wheel, but, as I shall show, the weight per wheel for a Fairlie narrow gauge engine—to do the same duty as an ordinary engine of 4 ft. 8½ in. —is less, and, therefore, the rails may be decreased, so that instead of—say a 64 lb. rail—a 45 lb. rail will be enough. The ties may of course be reduced to correspond. For a gauge of 3 ft. 6 in. sleepers 6 ft. long by 8 in. by 4 in. are ample, as compared with the 9 ft. by 9 in. by 4½ in. of an ordinary line, and in its turn the ballast is also reduced, because of the less stress coming upon it from the rail through the sleepers. Thus while we should require for a 4 ft. 8½ in. line with 64 lb. rails, ties of the scantlings given above, and ballast 9 in. below the bottom of the ties, we shall find, and experience bears out this statement, that on the 3 ft. 6 in. gauge with rails 45 lb. per yard, and ties 6 ft. long by 8 in. by 4 in., 6 in. of ballast below the ties will be sufficient. The saving in the materials of the latter construction will be:

In rails	30 per cent.
In ties	48 ,,
In ballast	44 ,,

The latter item would in reality be more, because I have neglected the effect of the formation slopes; the difference shown, however, is enough to establish General Buell's statement. On the other hand, the cost of permanent way fastenings would be almost the same in both cases; this is, however, but a small item. The approximate cost of rails for the 4 ft. 8½ in. gauge would be 9,500 dols. per mile, for ties 1,500 dols., and for ballast 3,000 dols. On the 3 ft. 6 in. gauge

this would be reduced to 6,650 dols., 870 dols., and 1,680 dols. respectively, equivalent to a total saving of 34 per cent.

I have assumed above only a direct proportional saving in the cost of sleepers for a 3 ft. 6 in. gauge as compared with a 4 ft. 8½ in., to show the actual reduction *if price decreased only in the ratio of the diminished scantling*, but in reality the cost is very largely reduced on account of the smaller sizes. In illustration of this I may mention that at the present time the same merchants are supplying me with sleepers for a 4 ft. 8½ in. line at the rate of 2s. 8d. per sleeper, and with others of exactly similar quality for a 3 ft. 6 in. line at 10d. each. The reason of this is, of course, because the larger scantlings cut to waste, while the others can be produced out of smaller, and consequently cheaper, timber. In a mile of average single track are 2,112 ties, so that at the prices I am now paying, the comparison would stand thus :

For the 4 ft. 8½ in. gauge 2,112 ties at 2s. 8d. = £281 12s.
For the 3 ft. 6 in. gauge 2,112 ties at 10d. = 88 0

So that while the saving in material is 48 per cent., the actual cost is considerably less than one-third.

Upon this showing, General Buell's estimated saving on the superstructure is as reasonable as that which he claims for the works up to formation. Let me now consider the characteristics of the line obtained at this reduced cost, as compared with the standard broad gauge line with which I have been making the comparison. We shall have a line 14½ in. narrower in gauge, with a reduced formation width, with heavier gradients, sharper curves, and lighter rails, and therefore it may be argued of less carrying capacity and efficiency ; but this is the point to which I now wish to call attention, and I maintain that, properly worked, such a line is at least as efficient as any broad gauge. I admit at once, that if the narrow gauge be regarded only as a reduced copy of the larger one, its capacity and efficiency decrease in a more rapid ratio

than its reduction in width, for if locomotives of the ordinary type be employed, the light rails and the narrow space between them limit the power, the heavy gradients still further affect the load to be carried, and the sharp curves may again set a limit to the wheel base. Therefore I say that such a line as I have been considering would be useless except under very special circumstances where small traffic and low speeds were required. Such an example exists in the Broelthal Valley Railway with a gauge of 2 ft. 7 in. and miniature rolling stock of the orthodox type. We must look, therefore, to a totally different method of working narrow gauge railways if we are to make them as efficient as the broader lines. We must have engines whose power is not limited by the width apart of the rails, to draw the heaviest loads required, and the same engines, whilst possessing ample weight to mount the ruling gradient and full capacity for traversing the sharpest curves, must still throw upon the rail a minimum weight per wheel. Given such a locomotive, and all the alleged inefficiency of the narrow gauge vanishes, and the advantages it possesses are developed. The chief of these advantages is the facility it gives of establishing *a fitting proportion between the weight of the vehicle and the load it has to carry*—in other words, the reduction of dead weight. As the most important feature connected with railway economy and the narrow gauge theory, this question of dead weight and engine power should have been first discussed, but in following Mr. Seymour's arguments I have been compelled to invert the order of things, owing, as I said, to that gentleman having assumed the least important point to be of the most consequence. For this reason I have been obliged to anticipate argument by conclusions, and to make assertions before I have shown them to be correct (I speak, of course, only with reference to this pamphlet; in the numerous documents I have already given to the world I have demonstrated the problem with the utmost clearness). These arguments will fall into

their proper places as I follow up the thread of Mr. Seymour's "Review."

And here I may be met by the temporising advocates of light construction on a broad gauge, those engineers who, admitting, as they are forced to admit, that the standard system is too costly, wish to effect a compromise by preserving their cherished gauge, and building a light road. They say: "We, too, will have surface lines" (which I was the first to advocate in 1864). "We will have the same steep gradients and sharp curves as you have on your narrow gauge, the same weight of rails; the same railway, in short, as you propose, excepting that the rails shall be wider apart by 1 ft. 2½ in. We shall have, it is true, the slight increase of cost due to the centre width; but we shall have all the advantages of the broader gauge, and as we shall not be isolated from other railway systems, we shall avoid the serious evil of loading and unloading our cars in making transfer of freight from one line to the other." To which I reply that the difference of cost even of such a line would still be of great importance over long routes of scant traffic, that if ordinary engines be employed, they must be made lighter than the Fairlie engine, which distributes its weight over so many points; the maximum weight per wheel being fixed by the rail, the power of the broader gauge ordinary engine would be greatly lessened, and besides this reduced power, the dead weight of vehicles would be increased, again subtracting from the useful work of the engine, so that the latter would be labouring over the compound disadvantages of limited weight available for adhesion, and of having to carry behind it a greater proportion of dead weight in its rolling stock. To overcome this acknowledged drawback, the expedient of coupling two engines back to back has been tried, but it requires small consideration to show that this is but a poor makeshift, for if the whole of the adhesive weight be utilised, either a long rigid wheel base, or unsteady running engines, which cannot take the curves freely,

is the result; if a forward bogie be added, the engine adapts itself to the curves at the expense of much adhesive weight, whilst if such a pair of engines be uncoupled and worked separately (which is one of the advantages claimed by the advocates of this system), the individual duty of each is comparatively insignificant, whilst double the cost would be incurred for labour in driving two engines coupled together.

With regard to the exact amount of saving to be obtained by the adoption of a substantial narrow gauge, instead of a so-called "light broad gauge," I cannot do better than briefly refer to what has already been proved by experience, and give the opinions of some eminent engineers. I have already mentioned that Mr. Carl Pihl was enabled to construct light railways at an average cost of £6,350, and we have seen the estimates for the Toronto, Grey, and Bruce Railway of Canada.

These stood as follows, for the same route :—

For the 3ft. 6 in. gauge per mile, 13,000 dols. without rolling stock.
For the 5ft. 6 in. „ „ „ 18,000 dols. „ „ „

For the rolling stock in each case 2,000 dols. per mile was allowed. If we reduce the cost per mile of the light 5 ft. 6 in. gauge to one of 4 ft. 8½ in. the cost per mile would be about 15,000 dols., or 15 per cent. more than the narrow gauge.

The estimates submitted by Mr. John Fowler to the Indian Government as to the comparative cost of the 5 ft. 6 in. and 3 ft. 6in. are so carefully and precisely worked out that I reproduce them here.

In these estimates exactly the same conditions are preserved for obtaining two lines of equal strength, (see note on page 34,) the proportions only are fairly reduced. The total cost per mile of the light 5 ft. 6 in. railway would be £5,397, as compared with £4,543 per mile on the 3 ft. 6 in. gauge, or a saving of 16 per cent. on the smaller gauge. This percentage would of course be reduced, if the comparison with a 4ft. 8½ in. gauge was adopted; but even then 10 or 12 per cent. would rest in favour of the narrow gauge.

I.—Estimated Cost of Light Railways from Kotree to Moultan, and from Lahore to Peshawur.

Gauge, 5 ft. 6 in.—Weight of rails, 42 lb.

Kotree to Moultan—480 miles.

	£	£	£
Earthwork (based on Mr. Brunton's quantities.)			
(14 ft. formation), per mile, £295·2	...	141,698	
Permanent Way.			
Rails (including 1-12th for fastenings) 72 tons at £14	1,008		
Sleepers (8 ft. 6 in. by 9 by 4½) 2,000 = cubic feet say 4,800 at 3s. 4d.	800		
Ballast (1 ft. 3 in. deep) cubic feet 70,000 at 10s. per 100...	350		
Laying...	90		
	2,248		
10 per cent. for sidings	224		
Per mile	2,472	1,186,560	
Bridges.			
Indus, 2,555 ft. at £46 ... ... say	120,000		
Sutlej, 3,520 ft. at £38 ... ... say	135,000		
Narra, 2,560 ft. at £29 ... ... say	75,000		
Minor bridges, per mile, £125	60,000		
= 812·5 per mile	...	390,000	
Telegraphs, Road Crossings, and (partial) Fencing.			
Telegraphs at £100 per mile.			
Road Crossings at £40 „			
Fencing at intervals at £17 „			
£157	say	75,200	
Stations and Workshops.			
Workshops	60,000		
Four large stations at £20,000	80,000		
Four secondary stations at £8,000	32,000		
Thirty-two small stations at £4,000	128,000		
= £625 per mile	...	300,000	
			2,093,458
Engineering and Agency.			
5 per cent. on English expenditure } 20 per cent. on Indian expenditure }	...	...	261,682
			2,355,140
Contingencies, 10 per cent.	...	...	235,514
Total, without rolling stock ... ... = £5,397·2 per mile	...	...	2,590,654
Rolling Stock.			
100 engines at £1,650	165,000		
1,200 vehicles at £200	240,000		
		405,000	
Agency and contingencies, 15 per cent.		60,750	
Total for rolling stock, £970 per mile	...	...	465,750
Total Cost	...	...	3,056,404
Kotree to Moultan (5 ft. 6 in. gauge), 480 miles at £6,367·5 per mile.			

2. Estimated Cost of Narrow-gauge Railway from Kotree to Moultan.

Gauge, 3 ft. 6 in.—Weight of rail, 42 lb.

Kotree to Moultan—480 miles.

	£	£	£
Earthwork.			
(10 ft. 6 in. formation), per mile, £258 ... ... say	...	123,800	
Permanent Way.			
*Rails and fastenings, 72 tons, at £14...	1,008		
Sleepers (6 ft. 3 in. × 8 × 4), 2,000 = 2,954 cubic feet, at 3s. 4d.	492		
Ballast (1 ft. deep), 42,000 cubic feet, at 10s. per 100	210		
Laying, per mile	80		
	1,790		
Add 10 per cent. for sidings	170		
Per mile	1,960	945,120	
Bridges as Before.			
= £729 per mile	...	350,000	
Telegraphs, Crossings, and (partial) Fencing.			
At £157 ... ... say	...	75,200	
Stations and Workshops as Before.			
= £558 per mile	...	268,000	
			1,762,120
Engineering and agency	...	...	220,315
			1,982,435
Contingencies, 10 per cent.	...	...	198,243
Total without rolling stock ... ... = £4,543 per mile.	...	...	2,180,678
Rolling Stock.			
100 engines at £1,600	160,000		
2,000 vehicles at £120	240,000		
		400,000	
Agency and contingencies, 15 per cent.	...	60,000	
Total for rolling stock ... ... = £958·33 per mile.	...	...	460,000
Total cost	...	...	2,640,678
Kotree to Moultan (3 ft. 6 in. gauge), 480 miles at per mile £5,501·4.			

I shall show further on what amount of weight that favourite argument of the broad gauge party has, touching upon the cost of transferring goods from one line to another, at the points of contact of two varying gauges. But I may briefly refer to it in

* Mr. Fowler has omitted to credit the narrow gauge with the difference in the weight of rail to carry the narrow gauge stock compared with the heavier broad gauge stock of equal capacity, also in the saving in the stock itself. This will be found fully explained on pages 38 to 41.

this place, because the adoption of the "light" broad gauge is recommended to a great extent for this reason, and the cost of shifting goods from one line to the other has been estimated at no less than 2s. per ton. I am very glad to find that Mr. Seymour and myself are not at issue upon this point, and I thank him for the valuable information he has contributed. The price which he gives (3½d. per ton) may be considered an outside figure for general merchandise, and upon several narrow gauge lines on the continent the freight is shifted for 2d. and even for 1½d. per ton. But if we take the price to be 3½d. it is plain that the annual cost for shifting is but a small additional charge upon the working expenses of a line, nothing in comparison to the saving in first cost of construction. Moreover, even if the "light" broad gauge line could be constructed as cheaply as a narrow gauge, there would still remain the constant and inevitable disadvantages attendant upon the extra amount of dead weight to be pulled, not only the dead weight due to the larger and heavier construction, but that resulting from the constant haulage of such vehicles very partially loaded. Thus both in construction and in working, everything tells against the "light" broad gauge, and in favour of the narrow, and simply because the latter *is more nearly adapted to the requirements of traffic than the former*. Even in the cost of maintenance and repairs of permanent way, the narrow gauge has a great advantage, because the number of tons carried over it is less by just so many as the number of tons of dead weight in the rolling stock is reduced.

I think I have adduced enough evidence to show that, even if the advocates of broad gauge abandon their cherished notions of heavy construction, and adopt the lightest form possible, a large saving can still be effected by reducing the gauge, with the result of obtaining a strong and efficient line as compared with one of "flimsy" construction.

I have referred to the Denver and Rio Grande 3 ft. gauge railway as a work of special interest, affording, as it does in a

great measure, the practical test that Mr. Seymour has so earnestly desired, that of two roads of differing gauges constructed under the same circumstances and over similar ground. But it will not be long before numerous similar examples will be available for comparison, because narrow gauge has taken deep root in the United States, and is throwing out vigorous branches all over the Union. In almost every State and Territory, from the eastern to the western seaboard, narrow gauge railways are being projected or commenced, especially in those districts where an almost uninvaded field is open, and where railroad construction is in its infancy.

In California, Montana, Utah, and Colorado, engineers are rapidly building roads upon the gauge I have strenuously advocated, and are finding readily the capital for their undertakings, which would have been impossible if a more costly system had been adopted. For a moderate capital is advanced with confidence for the completion of any sound scheme which shall not be burdened with an excessive outlay that swamps all possible immediate return. It is difficult to realise the benefit that will arise from this energetic advance, and how much more rapid will be the growth and the development of those vast and rich territories, over which the people of the United States, and the flood of emigration which sets steadily and increasingly towards America, is extending itself.

The great vital force which is characteristic of America, and which during the last twenty-five years has worked such marvels, needs but the means of communication to increase tenfold the results it can achieve. To expend hundreds of millions sterling in railway enterprise to this end will be needful before the vast expanse of territory, rich in all natural resources, shall be connected with the eastern and western seaboards, and a system by which this end can be achieved most economically and efficiently will be the only one that can be ultimately adopted.

The results that have been obtained upon the Denver and

Rio Grande Railway are no exceptional ones, but may be relied upon as representing the average saving that can be realised by the narrow gauge. And no more striking proof is required of the appreciation of many American engineers of the truth of my arguments than the fact that they are daily putting in practice the assertions which I have always advanced, and that they are now building thousands of miles of line as rapidly as work can be executed upon the principles I have consistently laid down. The prejudice so prevalent elsewhere finds but a small place in the minds of the western engineers, whose great aim is progress.

The statement in Mr. Seymour's sixteenth paragraph is true, that the weight of the rails is governed by the weight resting on the driving wheels of the engine, but the ordinary conditions are totally changed by the employment of the Fairlie engine, which gives a power on light rails and narrow gauge equal to any power which can be obtained by the ordinary system on the broad gauge and heavy rails. It may be argued that the Fairlie engine may also be employed on the broad gauge; this is true, and supposing that sufficient traffic existed, the advantage would be great; but even then it would be impossible to obtain the same amount of power with the same weight per wheel that is obtained on the narrow gauge under the same circumstances. On the wide gauge, the weight per wheel being constant, the engine *must be less powerful than on the narrow.*

I pause here to give an instance of the value of the Fairlie engine on the standard gauge, where there is ample traffic with fully-loaded wagons. We cannot do better than take the coal traffic from the northern counties to London. A Fairlie engine, with much less wear and tear to itself and the rails, will bring to London coal trains of *twice the weight now taken* by the best type of ordinary engine, and at the same speed. Just imagine the economy this would produce, leaving out of consideration the enormous advantage which would arise from

clearing the line of just half the present number of coal trains, with half the cost of labour, and a saving of from 20 to 30 per cent. in fuel. This saving alone would very materially add to the shareholders' profits. But to this proposition I receive for answer—that these trains would be too long for our sidings, which would all require to be lengthened, &c. Just fancy such reasoning coming from men who send back *double the number of wagons empty per train that are brought up full*, for which siding accommodation has to be found *now!*

This reduction in power is due to the increased weight of inert material required in the construction of the larger engine, and because the whole of this extra weight enters into those parts of the machine which in no sense add to the generative or distributing forces of the engine, and which, moreover, consume power in being carried.

The principal parts that are of necessity heavier are the axles and the cross-bracing between the frames and cylinders, and all of which—to be of equal strength—require not only to be so much longer on the wide gauge, but to be stronger in section, and this reacts upon the parts to which they are connected, causing them in turn to be larger and heavier; thus, for instance, the axles being of greater diameter, require heavier wheels, axle guards, boxes, &c., &c., and the result of this is, that the increased sections and weights required to make the wide gauge engine equal in strength to the narrow will represent the proportional difference in power between the two engines if reduced to the same weight per wheel.

For example, if the frames, wheels, and axles of two four-wheeled bogies for a 3 ft. 6 in. Fairlie engine (and the same argument holds good for all classes of rolling stock) weigh 14 tons—to obtain the same strength and stiffness in the frames, wheels, and axles of two similar four-wheeled bogies for a 4 ft. 8½ in. gauge, the weight would be at least 16 tons, and consequently, to make the narrow engine weigh the same as the

wide, the two additional tons could be placed in the power-giving parts of the locomotive, namely, the boiler and cylinders —the productive and distributive parts; and these combined would materially increase the tractive force of the narrow gauge engine over that of one of the wide gauge of similar weight per wheel. Practice has proved this conclusively.

Pursuing Mr. Seymour's argument in this paragraph, these unalterable conditions imposed upon broad and narrow gauge engines completely upset his theory; if it be true, and no one can dispute it, that the rails are adapted to carry the weight per engine wheel, without reference to the traffic, then it follows that the rails for a narrow gauge line, worked by engines of equal power to those of the wide gauge, need not be so heavy, and may be made lighter in proportion to the difference between the weight of the two locomotives of equal power, or if the weight per wheel be kept constant, then the narrow gauge engine being more powerful will necessarily take greater loads, and hence the capacity of a narrow gauge line, with equal weight of rails, will be considerably greater than a broad gauge one. These are the facts, and Mr. Seymour may exercise his ingenuity to design a new "theory" to combat them.

It must be clearly understood that, unless for a very small traffic combined with very low speeds, I do not, nor have I ever recommended a gauge narrower than 4 ft. 8½ in., if the ordinary type of engine be employed, because, and apart from the fact that the oscillations and unsteadiness of the ordinary engines increase as the gauge is diminished, *the width of the gauge limits the power of the engine, inasmuch as it limits the width of the fire-box, and the size of the boiler*, and as the loss of power increases even in a greater ratio than the diminution of the gauge, it follows that the carrying capacity of gauges narrower than 4 ft. 8½ in., when worked by ordinary engines, becomes limited in a very marked degree; whereas the point I maintain is that a 3 ft. or

3 feet 6 in. gauge properly worked is fully as efficient as the widest gauge railway ever built. Moreover, on account of the unsteadiness inseparable from small engines of the common type, the speed of trains, if the same factor of safety be preserved, must be reduced.

Now with the Fairlie engine, all these restrictive conditions are entirely changed; first, because the width of fire-box is entirely *independent of the gauge;* and second, because of the total absence of unsteadiness in running, and hence the power is unlimited, and equal safety at high speed is secured. These are not mere assertions. The power of facts has long since incontestably proved them to be true, and they are universally admitted by all those who have had experience of the Fairlie engine; one of them at least, the absence of oscillation and of flange friction on the rails, has been long accepted by every engineer in America, as proved by the universal adoption of double bogie rolling stock, which has enabled trains to be run at high speeds upon lines where English stock would not have kept the rails at all.

> *Paragraph* 17.—"The saving in the cost of each car will only be the value of a longitudinal section of 1 ft. 2½ in. taken from the centre of each car, embracing only the top, bottom, and two ends of the vehicle, and perhaps a still further trifling deduction on account of the value of materials and labour claimed to be saved in the construction of cars of the proposed diminutive width; but I claim that the additional number of cars required to transport the same amount of tonnage, or number of passengers, will make the cost quite as much, if not more, for the narrow than for the wider gauge."

The reasoning in this paragraph is exceedingly superficial—if, indeed, it is not intended as a cloak to hide the imperfections of the broad gauge rolling stock; but for the moment we will close our eyes to this, and follow out Mr. Seymour's reasoning.

Supposing a longitudinal section of 14½ in. be taken out of the

centre of a carriage or wagon, as described, does it follow that to obtain the transverse strength in each vehicle the sections of material used in the parts before they were cut should remain the same? It is tantamount to making a parallel beam, the section of which has been calculated for a span of 50 ft., suitable for one of 37 ft., by cutting the difference in length out of its centre; if this be done, how much stronger will the girder be for the 37 ft. than for the 50 ft.? The same reasoning applies to the reduction by 14½ in. in the length of the axles; but it must be remembered that there is another strain brought upon axles with fixed wheels, requiring a much larger section in proportion to their length—the strain of torsion. It will at once be seen that there is a great deal more to be taken from axles giving the same strength on the narrow as on the broad gauge than by merely cutting a certain length out of the centres. Mr. Seymour's fallacy of the "extracted prism" is extended here from the line to the rolling stock. In the same way, the sections of all the framings in the vehicle may be reduced.

The claim that additional cars would be required to transport the same amount of tonnage or number of passengers is as transparently fallacious as any of the preceding ones. In practice there are only two conditions which could give a partial air of correctness to this statement: first, *that each car should always travel with its full load in every direction*, and secondly, *that these cars should bear the same proportion of width to gauge that the narrow gauge cars now do.* Unless these conditions are complied with, Mr. Seymour's assertion is an idle one.

With regard to the first of these conditions, I see that it is admitted by all that the proportion of paying to non-paying load of merchandise hauled over the best worked lines in America, is ½ to 1, whilst the capacity of the stock employed is 18 to 10, showing that the existing freight stock is only worked to 27 per cent. of its full capacity. What, then, is the inference to be drawn from this? Simply that cars which were made to

carry 10 tons only carry for every mile that they run 2·7 tons, and this being no doubt a necessity arising from the exigencies of traffic, compelling quick delivery of goods between stations, does it not follow, taking Mr. Seymour's own view of the case, that cars reduced in width by 14½ in., and in capacity say 20 per cent., would be more than ample to accommodate the traffic, as it is now taken; and if so what becomes of the claim for an additional number of cars? These observations have reference to the merchandise traffic only, but when we come to consider the question of passenger traffic in the same light, the case against Mr. Seymour is greatly strengthened, because the passenger cars never carry more than one-fourth of their capacity, proving that narrow gauge stock would accommodate as much as twice the traffic carried on a broad gauge, and leave an ample margin.

In a paper read by me before the British Association at Liverpool, in August, 1870, I showed from actual statistics that the actual proportion of dead weight to goods carried in the United Kingdom, exclusive of mineral traffic, was no less than 7 to 1, while the proportion in passenger traffic was 29 to 1.

To a less degree, the same condition of things—a condition which is absolutely inseparable from the wider gauge—exists in France, as the following statistics, referring to the six chief lines of the country, will prove. In France, too, everything is in favour of the wide gauge, because the railway companies, engaging themselves in no great competition, fill the carriages to the utmost, and convey goods as profitably as they can for themselves, to the great detriment of trade interests; and, in fact, so much have the companies erred in this respect that a society has recently been organised in Paris, with the object of enforcing greater regularity and promptness in the delivery of merchandise on the part of the companies, and if they are successful in their endeavours, the result will declare itself in *a larger proportion of dead weight carried.*

In France, then, we find that on the six principal lines the proportion (in the passenger traffic) of seats occupied to those available are

On the Northern Line.....	0·223	General average, 0·240.
On the Eastern Railway.....	0·203	
On the Lyons ,, ...	0·269	
On the Western ,, ...	0·277	
On the Orléans ,, ...	0·234	
On the Southern ,, ...	0·277	

And the weight hauled per passenger is found to be:

	Tons.	
On the Northern Railway.....	·819	General average, ·742 tons.
On the Eastern ,, ...	·828	
On the Lyons ,, ...	·725	
On the Western ,, ...	·630	
On the Orléans ,, ...	·764	
On the Southern ,, ...	·634	

Whilst the average weight to be hauled per passenger, assuming all the seats to be occupied, would be ·235 tons.

Turning to the goods traffic, we find that on the average the French coal wagons weigh 4·5 tons, and can carry 10 tons, while the coke wagons weigh 4·180 tons, and carry 10 tons. The minimum dead weight per ton, according to the full load, is ·450 ton for coal, and ·418 ton for coke, or a mean of ·434, and the minimum weight of one ton, with its share of the vehicle, would be 1·434 ton. But in reality the average load per coal wagon is not 10 tons, but 4·903 tons, or 49 per cent., so that the real weight of a ton with its proportionate part of the wagon is 1·918 ton.

In the same way the ordinary goods wagons, weighing 5·1 tons, and built to carry 10 tons, really are loaded only with an average of 4·175, so that the proportion of dead to useful weight per ton is $\frac{5·1}{4·175}=1·221$, or 2·4 times the proper amount.

I think I have now proved to all fair and unprejudiced minds the fallacy of Mr. Seymour's arguments, from his own points

of view, as to the useful capacity and equal weight question, both as regards locomotives and rolling stock, and that, contrary to the conclusions he has arrived at, the narrow gauge is superior to the broad, and for this simple reason, that the capacity of the former *more nearly approximates to the requirements of traffic than the latter.*

I may now proceed to the second point of this consideration —the proportion of cars to width of gauge.

The merchandise and passenger traffic in the country to which Mr. Seymour addresses himself is for the most part carried in eight-wheeled cars, grouped in two four-wheeled bogies. This I unhesitatingly assert to be the most extravagant mode of carriage, so far as dead weight of rolling stock is concerned; but as it is admitted that bogies are necessary on American lines, for easy running over badly-laid roads, and for passing freely round curves, I presume, from the almost universal use of the bogie, that its advantages outweigh the drawback of dead weight. The average carrying capacity of four-wheeled goods stock, as compared to its dead weight, is 1·9 to 1, whilst that of the average eight-wheeled bogie stock is but 1·4 to 1, and this difference, of course independent of the advantage arising from the facilities of loading and handling which the smaller wagons offer, must certainly have long since insured their general adoption, had it not been for the practical reasons to which I alluded just now. If we inquire into the cause why the bogie stock holds its own on American railroads, we shall find, as I say, that the reasons lie chiefly in length of the extreme wheel base of the bogie stock, compared with that of the four-wheeled, and the freedom with which the wheels of the former follow the inequalities of the road, without transferring their effect to the vehicle itself, thus reducing the lateral oscillation of the load to a minimum, whereas with the four-wheeled stock such inequalities are transferred direct to the load, and hence the oscillations arrive at a maximum.

This condition of things is inseparable from all four-wheeled stock, and no doubt causes a considerable increase in the train resistances, but it is seldom the cause of the vehicle leaving the track in going round curves. This arises from the mode of coupling and the use of side buffers, which become jammed one with another on sharp curves, one wagon entirely supporting for the moment the end of another wagon, so that at times there is no weight on one, or perhaps two wheels, which under such conditions are often relieved from load. This jamming and the results described often happen, but fortunately without causing the wagons to leave the rails.

Mr. Seymour, and those who argue with him, may ask me what all this has to do with the question under consideration. I reply that it is all-important, because, in showing the reason why, with its acknowledged drawbacks, bogie wagon stock has been adopted in the United States, in preference to the lighter four-wheeled stock, I approach one grand advantage of the narrow gauge, which, were it not proved, my argument would fail; but when I show that those reasons which prevail against four-wheeled stock on the wide gauge almost cease to have any existence in four-wheeled stock on the narrow gauge, I believe I shall have established my case.

The great length of wheel base necessary to get a steady running vehicle on the broad gauge, is the principal objection to four-wheeled cars, and to those of the broad gauge advocates who urge, as Mr. Seymour now does, that the wheel base may be reduced in proportion, I reply that if you reduce the wheel base of the broad gauge stock to the dimensions of the narrow gauge, you get a most dangerous rolling stock, and one difficult to manage, the friction per ton of which would be fully double that of the bogie stock, owing to its great lateral oscillation.

To obtain anything like steady-running four-wheeled stock, the wheel base should be at least twice the width of the gauge. Of course a smaller proportion than this will serve, but

the more it is reduced the greater is the friction, and the more the liability to quit the rails, while on the other hand, if this proportion is maintained, curves cannot be freely traversed on the wide gauge, and the dimensions of the wagon exceed by far what is required of them; besides, such a stock would be very difficult to handle. Now on the narrow gauge all the desiderata are combined without one disadvantage; by a 3 ft. gauge a 6 ft. wheel base is given, and this is the right proportion of length to gauge, a perfectly steady running machine is obtained, and one that will pass freely round curves of 150 ft. radius, whilst 4 ft. 8½ in. stock built of the same proportions would give 9½ ft. of wheel base, and this length, together with the greater amount of slipping, due to the greater distance between the rails, would render the passage of sharp curves not only difficult but dangerous.

The width of the stock that can be obtained on the narrow gauge is another point in its favour, because the *greatest width the gauge will permit of can be obtained without a special strengthening of parts*, and at the same time a proper centre of gravity can be maintained. Besides, such stock is never unwieldy, cumbersome, or difficult to manage at stations. Experience has shown that for considerable speeds freight cars for a 3 ft. gauge can be built 7 ft. wide, or 2⅓ times the gauge, and that this is a most convenient and cheap size for managing general traffic. But it would be equally impossible and undesirable to obtain on the 5 ft. 6 in. or 4 ft. 8½ in. gauge a rolling stock 2⅓ times the width, for on the former the stock would be nearly 13 ft. wide, and on the latter it would be nearly 11 ft., and these dimensions, even if they could be obtained, would make the stock most unhandy, and out of all proportion to the size required by any traffic.

It will be seen, therefore, that a 3 ft. gauge, and after that one of 3 ft. 6 in., gives the greatest width of cars the gauge permits, and consequently *the utmost usefulness of the gauge*

is developed, whilst at the same time such stock as I propose is most convenient to handle, in construction the *maximum strength with the minimum of dead weight can be secured, and nearer a full measure of capacity obtained.*

This light stock saves the rails, reduces maintenance of way, diminishes the wear and tear of the stock itself; finally, it saves in the amount of fuel consumed and tractive power required. In evidence of the enormous cost of maintaining broad as compared with narrow gauge stock of equal capacity, I do not think I can do better than quote a letter on the subject which recently was published in the money article of the *Times*, written by the manager of the Gloucester Wagon Company, one of the largest firms of its class in this country; the writer, Mr. Slater, is acknowledged on all sides to have a wider experience on the subject of dispute than any other English engineer:

"Gloucester Wagon Company, Limited,
"Gloucester, Sept. 21st, 1871.

"DEAR SIR,—Referring to the conversation that I had with you yesterday on the comparative merits of broad and narrow gauge railways, so far as that question affects the cost of construction of rolling stock, I don't think I can give you my opinion in a more forcible manner than by relating what I said to Mr. Potter when he was made Chairman of the Great Western Railway, now about eight years ago, and now President of the Grand Trunk Railway of Canada.

"I recommended Mr. Potter, in the strongest terms I could use, to commence the conversion of the broad gauge into narrow; by 'narrow,' I meant, of course, the established gauge of the country, 4 ft. 8½ in. I followed up the advice by one or two illustrations; for instance, I said if a colliery proprietor applies to me for terms for the hire of 10-*ton broad gauge* wagons and 10-*ton narrow gauge*, I should ask £18 *a-year* for the former,

and £12 for the latter, and I should use *all my influence to persuade him to take the narrow gauge.* I then said this applies to wagons that always carry a full load, but if you apply the same mode of comparison to merchandise wagons, as used by railway companies, you will find the difference still more striking, and especially so when applied to 'dead weight' and 'paying weight.' For instance, it is found that on narrow gauge railways which pass through the manufacturing districts, the average load of a *loaded wagon* does not exceed 30 cwt.;* if this is so on those lines which serve the manufacturing districts, it is scarcely to be expected that you would get a better result on the broad gauge system, which passes through an agricultural district. What then is the result? Simply this: you have got on the broad gauge wagons, the first cost of which, and the cost of maintenance, is very largely in excess of the same items on the narrow gauge, whilst you have also, on the broad gauge, a dead weight of from 5 tons 10 cwt. to 7 tons, for a paying load of 30 cwt.; on the narrow gauge you have a dead weight of 3 tons 10 cwt. to 4 tons for the same paying weight.

"The above is, in plain words, the conviction which I had formed, and which I expressed to Mr. Potter eight years ago, and I have seen no reason to alter my views.

"Yours faithfully,

(Signed) "J. SLATER.

"R. F. Fairlie, Esq."

Mr. Seymour grants General Buell's third reason for the adoption of narrow gauge—namely, that speeds of from 35 to 45 miles an hour may be attained on it with perfect safety. The expression "perfect safety" must, of course, be taken in a qualified sense, for there is no such element upon any gauge. But what General Buell urges, and Mr. Seymour concedes is,

* This is exclusive of empty mileage run by wagons, which would certainly reduce this proportion to one-half, or 15 cwt. only for every mile the wagon runs.

that such a speed may be practically obtained on the 3 ft. 6 in. gauge. Ample experience proves that this is correct, as on the Norwegian, Queensland, and Livny Railroads of 3 ft. 6 in. gauge, and on the 2 ft. Festiniog, 35 miles an hour have often been made, and, as Mr. Seymour says, there is "no reason why an engine of sufficient power will not haul a train with as great speed and safety upon a narrow as upon a wide gauge."

> *Paragraph* 18.—"I claim also that the cost of locomotives, provided the same amount of power is used, will be no greater for the wide than the narrow gauge. If there is any difference, it would certainly be in favour of the largest engine."

This paragraph would be scarcely worth noticing, if it were not so absurd. Engines of equal power are assumed in each case. Taking, then, the case of the most powerful engine of the ordinary type that can be placed on a 3 ft. 6 in. gauge, can it be possible that Mr. Seymour wants us to believe that the same boilers, cylinders, &c., mounted on the wider and heavier substructure involved by the 4 ft. 8½ in. gauge, would absolutely weigh less than the smaller engine, with its smaller, lighter framing? As I have shown, the Fairlie engine is independent of gauge, but (power in each case being equal) the reduction in weight, and therefore the reduction in cost, must follow, if for no other reason than that builders construct locomotives at so much per pound of their weight.

We now arrive at the consideration of the fifth and last reason advanced by General Buell, and the one most warmly contested by Mr. Seymour. General Buell claims that the percentage of dead weight to load chargeable to the 3 ft. 6. in. gauge is $\frac{47}{100}$, and that the same item chargeable to the 4 ft. 8½ in. gauge is $\frac{75}{100}$, making a difference of $\frac{28}{100}$ in favour of the former; and he states that he has based his calculations upon the existing wide gauge stock, and that constructed for the Denver and Rio Grande Railway at the Wilmington Car Works. Mr. Seymour,

to my thinking, goes out of his way to sneer at this small stock, forgetful that the gentlemen who control the Wilmington Car Works are able and experienced engineers. But as Mr. Seymour declines to admit anything which has not been demonstrated by practice, I must turn to actual examples to prove how far General Buell is correct. Experience has shown that on the wider gauges it is impossible to utilise to the full extent the broad base which the rails offer. This is because the vehicles would be large, out of all proportion to their requirements, and because they would be inordinately heavy. This is a point to which I would call special attention, for in it lies one of the chief features of narrow gauge. I claim that the width of 3 ft. or 3 ft. 6 in. (though, be it remembered, all gauges are empirical) is the most suitable width upon which to base the proportions of the rolling stock, most economical, and most efficient. It will be granted, I think, that the width of gauge ought to bear a fit proportion to the economical width of the rolling stock. Now, on the 5 ft. 6 in. gauge of India, the width of rolling stock is only 8 ft. 6 in., and on the 4 ft. 8½ in. gauge the average width of vehicles is about the same. And this fact illustrates the point to which I am alluding. The Indian rolling stock could have been placed with perfect propriety on the 4 ft. 8½ in. gauge, and a large saving in construction expenses would have been made. On the other hand, the rolling stock ought to have been made at least nearly 13 ft. wide, but had this appropriate width been adopted, the proportion of dead to paying weight would have been far more excessive than it is at present, because such carriages and wagons would have been of necessity much heavier in their construction, and their increased capacity would have served no good purpose, for if the amount of traffic can only now half fill the vehicle, properly-proportioned stock would have to run only one-third or one-fourth full.

And the same thing to a rather less degree is true of the 4 ft. 8½ in. gauge. The rolling stock is not, and never can be,

fully loaded by general traffic, and yet it ought to be made more capacious to bear a proper relation to the gauge. Now, if it were possible so to arrange the traffic of any given line that properly-proportioned stock should always be conveyed fully loaded, the cause for which I argue would not be so clearly established, but it is impossible to arrive at such a state of things. We have seen how the proportion of dead weight to paying load increases from the French railways, where practical monopoly reduces this dead weight to the utmost, to the English and American lines, where free competition compels extravagant working. It is certain that on the present system dead weight increases with prompt management. It cannot be otherwise, as the association now formed in Paris to compel prompt action on the part of the railway companies will find, should they succeed.

And the whole of this dead weight, and the enormous expenses it entails, arise from the simple fact that rolling stock is disproportioned to the traffic. The great object of narrow gauge is to do away with this disproportion, to make the UNIT OF CAPACITY APPROXIMATE TO THE AVAILABLE UNIT OF LOAD, and of course to obtain a proper proportion between width of gauge, and dimensions, and dead weight of vehicle, and at the same time to combine with these desiderata, *prompt* and *efficient management.*

Take an example: The standard passenger cars in the United States, running on the two four-wheeled bogies, seat 56 passengers; they are about 46 to 48 ft. long, and vary from 8 ft. 6 in. to 10 ft. extreme width, and they weigh empty 15 tons; that is equal to a dead load of 4 to 1 of paying load; but under ordinary circumstances the cars are only half filled, which doubles the dead weight, and the average dead weight of passenger stock on the New York railways is 18 to 1. In England a worse state of things prevails. Turn now to the carriages of the Norwegian railways, and I venture to think Mr. Seymour

can scarcely question the experience these lines give us. Mr. Pihl's stock is somewhat heavy, but his latest patterns weigh 4·6 tons and 3·9 tons, to seat 32 passengers, giving ample space and accommodation. These weights are only 2·15 to 1 and 1·82 to 1 respectively, allowing 15 passengers to the ton. Again, on the Livny Railway they are 2·5 to 1; on the Novgorod Railway they are 2·7 to 1; on the Dunedin and Port Chalmers Railway, New Zealand, they are 1·75 to 1. It will be noticed that the Norwegian proportions are unfavourable to the question. Still, if we compare them with those of the American stock, we find that they are more than General Buell has claimed ($\frac{47}{100}$ and $\frac{75}{100}$), based upon the Denver and Rio Grande stock.

Taking next the wagons, I believe that the average dimensions and weights used in the States are as follows:—Freight cars 30 ft. to 36 ft. long, and from 7½ ft. to 9 ft. wide over all, running on 8 wheels, and weighing 9 to 11 tons. Platform cars about the same weight: coal cars 12 ft. long and 6½ ft. extreme width on 8 wheels, weighing 6 tons and carrying 10 tons, whilst the 9 ton ordinary freight car carries 13 tons, the proportion of load to wagon being 1·4 to 1. On the Broethal Valley line (2 ft. 7½ in. gauge) the proportions are 2 to 1; on the Novgorod Railway they are 3 to 1; on the Tavaux Ponsericourt (3 ft. 3 in. gauge) they are 3 to 1; on the Festiniog, 3 to 1; on the Livny Railway, 3 to 1; on the Dunedin and Port Chalmers, 3 to 1; on the St. Leone (2 ft. 8 in. gauge), 3 to 1; on the Montepone line, 2·5 to 1. I could prolong this list if it were necessary, but I have said enough to show that while the railway experience of half a century can give no more than a proportion of 1·4 to 1·9 to 1 of paying to dead load on the 4 ft. 8½ in. gauge, a proportion of 3 to 1 can be, and is obtained successfully on the narrow gauge.

Thus, with regard to the freight stock, we find that General Buell's estimate of saving in dead weight, although founded upon theory, is thoroughly substantiated by a wide and extended practice. And it cannot be argued that because many

of the narrow gauge lines at work are but short and local railways, the experience they afford is not applicable to general practice. The Livny and other lines have shown fully what can be done by narrow gauge.

The facts I have brought to bear upon this part of the discussion prove conclusively: first, that Mr. Seymour is wrong; second, that General Buell is right; third, that while on the broader gauges rolling stock cannot be built in proper proportion, suitable dimensions can be obtained on the narrow; and, fourth, that assuming both passenger and wagon stock to be fully loaded on both gauges, the proportion of paying to dead weight for the former are 1 to 4, as against 1 to 2·15, and in the latter they are 1·8 to 1, and 3 to 1 respectively.

But even were the proportions of dead weight the same in each case, there would still remain a grand advantage with the narrow gauge—viz., the capability it possesses of adapting efficiently and economically the capacity of the vehicle to the load it has to convey.

Assuming for a moment that 200 passengers are to be conveyed by the passenger cars of the American type, each having 56 seats, and weighing 15 tons; four such cars would be required, so that three would be fully occupied, and the fourth would have 24 seats vacant; the total dead load of such a train would be 60 tons. On the other hand, of narrow gauge cars of 32 seats, and weighing 4·6 tons, 7 would be required to convey the 200 passengers, or equivalent to 32·2 tons of dead load. In the first case there would be 24 vacant seats in the 4 cars, representing 6 tons of perfectly useless load, and in the other there would be also 24 vacant seats, representing 3·42 tons of useless load. Or supposing that 180 passengers have to be conveyed, 4 wide gauge cars would also be required, weighing 60 tons, but 44 seats of one car would be empty, and the useless load would be 12·5 tons; but the same number of passengers could be conveyed in 6

narrow gauge cars weighing 27·6 tons, and there would only be 12 vacant seats, or 1·72 tons of useless load. As regards the passenger traffic, I need not push this comparison further, although I might go on to show that if the amount of accommodation provided were not in excess of the requirement, and by the narrow gauge stock alone can such an approximation be made, these proportions of dead weight would be still further reduced, and no such monstrous ratios as 18 to 1 could possibly exist. And taking the worst case, that in which the number of passengers exceeds the capacity of a given number of cars by 1, the proportions that would exist would be vastly reduced in the narrow gauge apart from the consideration of absolute weight per car.

With regard to freight, however, the matter is different, and the advantage becomes more striking for the narrow gauge. Further on I shall make a comparison between the two systems, on the most favourable terms possible for the wider gauge, that is, taking French experience, but it would be only fair to assume the existing conditions of English and American practice.

Mr. Seymour, like all broad gauge advocates, only regards the question of broad and narrow gauge from a constructive point of view, and does not advance beyond the consideration of cost in building and weight in the rolling stock of a line. But in reality this is a very minor consideration, and the narrow gauge could afford to give the difference in width which belongs to it to the broad gauge, and remain vastly superior to it, on account of the economy arising from working a small stock, with maximum loads, approaching as near as possible to the limits which railway practice dictates. The economy in dead weight, arising from the advantage in this respect which the narrow gauge confers, coupled with the power of the Fairlie engine to haul as great loads, at as high a speed, as are now conveyed on the best American lines must surely impress on all unprejudiced minds the advantage of the narrow gauge.

I have already shown how impossible it is to build a broad

gauge wagon of a suitable capacity (say 7 ft. wide and 14 ft. long) so light, and at the same time so strong, as one for a 3 ft. or 3 ft. 6 in. gauge, and so far as dead weight is concerned, I do not think that the position can be questioned. No one will, I imagine, venture to say that it is more economical to employ wagons, weighing 4 tons, to carry an average of 2 tons, whilst their capacity is 8 tons, than to run wagons weighing only 2 tons, with a maximum capacity of 6 tons, to convey the same load. Suppose these small cars of only half the weight, and two-thirds the capacity of the larger ones, carry the same average load, what then becomes of Mr. Seymour's argument about requiring so many extra wagons and an increased length of train? Does it not follow that under the conditions named not one more wagon will be required in the one case than in the other, and as regards length, must not the train, composed of the same number of wagons, be reduced to two-thirds the length of the wide gauge train, assuming the wagons have the same width in each case? while, if they are 20 per cent. narrower, the train having the same useful capacity, will still be 14 per cent. shorter than the wide gauge trains.

That the average load of merchandise carried upon railways of the present system must be, at the utmost, but half of that of the vehicles in which it is conveyed, will always remain a fact, so long as such railways are in existence, having an intermediate traffic to accommodate; the proportion of dead to paying weight must rise with competition, and where competition exists, the narrow gauge will be found most useful.

In illustration of this I will assume the case of coal traffic, which secures in one direction at least maximum loads.

The ordinary 4 ft. 8½ in. wagons weigh on an average 4 tons, and carry 8 tons, this being the outside proportion of load now carried to the weight of vehicle. With the 3 ft. 6 in. wagons 7 ft. wide, weighing 2 tons, and carrying 6 tons, we get 50 per cent. more weight carried per weight of wagon, and it is

evidently more economical to run 2 ton return empty wagons than 4 ton ones. Possibly Mr. Seymour may urge that if I build the 3 ft. 6 in. wagons double the width of the gauge, he may do the same with the wide gauge wagon, but he cannot do this without overloading his wheels and axles to a dangerous extent. A load of 12 tons is even generally as much as the present axles can safely carry. Besides, by doing this, he would only run up his dead weight. And here I may remark that the antagonists of the narrow gauge, while invariably denying the advantages claimed for it, generally assert, as each point is raised, that the same thing can be done better and cheaper on the broad. Is it urged that narrow gauge lines are cheaper to build? They can make broad gauge as cheap. Can the rolling stock be made lighter for narrow gauge? So it can on the broad. Can it be worked more economically? By effecting such or such a change equal economy can be effected on the lines they advocate. And yet these very antagonists to narrow gauge, while they do not hesitate to advance and to maintain the wildest assertions as to making and working cheap broad gauge, that neither experience nor common-sense can for a moment justify, they urge as one of the paramount objections to the change, that the experience of half a century is not to be set aside by new principles which must be wrong apparently only because they *are* new, forgetting that narrow gauge has been long and successfully established, and that they flatly contradict their orthodox principles by proposing all sorts of devices in favour of a width which one advocate asserted that George Stephenson adopted "in a moment of inspiration."

But not the most ingenious argument can change the fact that on the busiest lines traffic cannot be found to fill the present stock which has been from the first made disproportionately small for the gauge on which it has to run. And, as I have shown, even on mineral lines, a great advantage rests with the narrow gauge. Mr. Seymour may say that he can

make his wagon smaller; but if he does this, he must necessarily have a shorter wheel base than is compatible with steady and even safe running, and he must still contend against the increased dead weight. And, besides, such a line of argument is equivalent to the admission of the superiority of the narrow gauge, which gives the greatest amount of service at a minimum cost.

I have said that on the French system the freight stock is loaded nearer to its actual capacity than almost any other general system in the world, owing to the practical monopoly which the different companies enjoy, and that the actual proportion of carrying capacity to dead weight per wagon is about 2 to 1. In 1868 the statistics of freight service were as follows on six lines:—

Total train-mileage, about 3,000,000 miles.

Total ton-mileage, about 880,000,000 ton miles.

Average weight of freight and wagons per train, 294·751 tons.

Of which 127·598 tons were paying weight, giving a proportion of useful to total weight of 43·2 per cent., or less than half to one.

The weight of vehicle per ton of goods carried was 1·310 tons, that is to say, that the dead weight per train was 167·153 tons, or say 33 wagons weighing 5 tons each, and built to carry 10 tons, yet only having an average load of 3·86 tons, and this is the result under the most favourable circumstances.

Now, if this traffic had been conveyed upon the narrow gauge, the results would have stood thus:—

Average weight of wagons and freight, 193·598 tons.

Of which 127·598 tons would be paying weight as before, giving a proportion of useful to total weight of more than 65 per cent., or about two-thirds to one.

The weight of vehicle per ton of goods carried would be ·51 tons, that is to say, the dead weight per train would be 66 tons, or

33 wagons, weighing 2 tons each, and built to carry 6 tons, but only having an average load of 3·86 tons each. The saving in dead weight in each train is as 66 to 167, and this under the most unfavourable circumstances for the narrow gauge, the dead weight hauled over a distance of 3,000,000 miles would only be 35 per cent. of that of the broad gauge. Now the cost of traction of the whole of this tonnage was approximately £2,250,000, and the saving effected in this item alone, had the freight been conveyed per narrow instead of broad gauge, would have been £787,500.

All of these observations refer to the two paragraphs of Mr. Seymour's report last quoted, and to those which I insert below.

Paragraphs 19 to 41.—"If these statements are correct, and I have no doubt that they will be found substantially so, there can be no more force in the second and fourth propositions submitted by your chief engineer than there appears to be in the first."

"Having had some experience in the construction and equipment of roads, with both the 6 ft. and 4 ft. 8½ in. gauges, the difference in which is slightly greater than that of the two gauges now under discussion, I am not prepared to say, and do not claim, that there is actually no difference whatever in their first cost; but I do say most emphatically that this difference is very largely, although probably inadvertently, overstated by the advocates of this extreme narrow gauge theory."

"When, in 1847, this matter was under discussion before the New York and Erie Railroad Company, with reference to the proposed change of gauge from 6ft. to 4 ft. 8½ in., I know that this item, of first cost of construction and equipment, did not enter very largely into the argument; and my recollection is, that it was conceded by the respective advocates of each gauge, that it could not be less than five, nor more than ten per cent. in favour of the narrow gauge."

"The third reason given by your chief engineer seems to have very little, if any, application to his argument in favour of the narrow, as against the wide gauge. It seems rather to be introduced for the purpose of showing, or asserting, that a train upon

the narrow gauge is capable of attaining as high a rate of speed as is reached upon any first-class railroad. In putting this rate of speed at '35 to 45 miles per hour with perfect safety,' I believe him to be in error, because I do not think that such a rate of speed can be adopted with *perfect safety* upon any road, or with any gauge."

"With the track in perfect adjustment, and cars of proportionate width and height, I SEE NO REASON WHY AN ENGINE OF SUFFICIENT POWER WILL NOT HAUL A TRAIN WITH AS GREAT SPEED AND SAFETY UPON A NARROW AS UPON A WIDE GAUGE. Although I believe it is generally conceded that, in the ordinary condition of our roads and rolling stock, a wide gauge is the safest for high rates of speed."

"The fifth and last reason assigned by your chief engineer is really the *great* argument generally advanced by the advocates of the extreme narrow gauge theory. And yet I firmly believe it to be the weakest, and, if proper tests could be applied, the most easily exploded, of any of the arguments yet advanced in its favour."

"But the great difficulty here, as in the other positions assumed in favour of this theory, is to apply the proper test. If we could have two parallel roads constructed, of equal lengths, grades, and curves, but of different gauges; and if we could have a given amount of passengers, and of the same kinds of freight, to transport over each, within a given time, and could be allowed to try experiments, as to the most economical mode of doing it, the problem could very soon be solved beyond a question."

"Or, if any main trunk line had been constructed of the gauge recommended by your chief engineer, upon which a mixed freight and passenger traffic had been carried on during a series of years, the results of which could be compared with those of any other similar line, having the ordinary gauge, and doing the same amount and kind of business, we might then be able to procure some data upon which to base an argument."

"But as we have neither of these examples before us, every one is allowed to form his own opinions from his own stand-point; and to advocate them in any manner, and for any purpose he pleases, apparently without any fear of successful contradiction."

"It will be observed, however, that the entire argument is merely speculative, and that it is based upon pure assumptions, instead of upon facts as they are known to exist."

"Your chief engineer assumes, as his fifth and last reason, that the percentage of dead weight to load, chargeable to the 3 ft. 6 in. gauge, is $\frac{47}{100}$; and that the same item chargeable to the 4 ft. 8½ in. gauge, is $\frac{75}{100}$, making a difference of $\frac{28}{100}$ in favour of the narrow gauge."

"In another place he assumes that the percentage of dead to live weight upon the 4 ft. 8½ in. gauge, is 100; upon the 3 ft. 6 in. gauge, 48; and upon the 3 ft. gauge, 56."

"He also says: 'In the above calculation I have used for the 4 ft. 8½ in. gauge *the box car now in use.* For the 3 ft. 6 in. gauge, *the box car as presented in this report.* For the 3 ft. gauge, *the box car as constructed* at the Wilmington Car Works *for the Denver and Rio Grande Railroad.*' I have italicised the portions of the above quotations to which I wish to call particular attention; and will only add the remark that '*the box car now in use*' has been actually and thoroughly tested during many years, and has been found to answer the purpose admirably well; '*the box car as presented in this report*' exists only in theory and upon paper; and '*the box car as constructed for the Denver and Rio Grande Railroad,*' if really constructed, has never been used sufficiently to test either its strength or durability."

"The terminal stations of the New York Central and the Erie Railways are within easy reach of your office. The difference between their respective gauges is greater than between the 3 ft. 6 in. and the 4 ft. 8½ in. gauges. The general character of their business is the same; and it is to be presumed that their rolling stock has been constructed, as to weight and dimensions, with due regard to the width of their respective gauges. I would therefore respectfully ask whether it would not have been as well for your chief engineer to have been obtained from these sources some reliable data upon which to base his arguments, instead of basing them so entirely upon mere assumptions."

Paragraphs 33 *to* 41.—"But as he has not done so, and does not give any reasons, either satisfactory or otherwise, for this apparent discrepancy between dead and live weight upon the respective gauges, I would respectfully ask him why this percentage is necessarily greater upon the 4 ft. 8½ in. gauge, and less upon the 3 ft. gauge, than it is upon the 3 ft. 6 in. gauge. And will he, or any other of the many advocates of this extreme narrow gauge theory, undertake to demonstrate why a platform ten feet square,

and capable of upholding a given maximum weight, should necessarily be of *more* than twice the weight and strength of one ten feet long and five feet wide, and capable of sustaining just one and a half of the same maximum weight? And, again, if an ordinary four-wheel truck, duly proportioned to the size and weight of the respective loaded platforms, were to be placed underneath each platform, why it should necessarily require *more* than twice the power to move the larger that it does to move the smaller platform?"

"These may be regarded as very trifling and unimportant questions. Yet, simple as they may appear, I am very much mistaken if they do not reach, and effectually undermine, the foundations of this narrow gauge theory, so far at least as it rests upon the great *dead weight* argument."

"In the absence of any actual test, or other demonstration, I will venture the opinion that the larger platform, if constructed only of equal proportional strength, will be found to be of *less* than twice the weight of the smaller one; and also, that *less* than twice the power will move it."

"If there be even a slight possibility that my opinion is correct, then why not try, at least, this very simple and cheap experiment at once, instead of expending millions of dollars upon what must at best be regarded as a very questionable theory? The trial may be made at almost any time, upon any road, and with any gauge, by merely making a proper allowance for the unnecessary length and size of the axles underneath the smaller platform; and the experimental platforms may be of any relative width required to furnish the superficial area or bearing surface claimed for the respective gauges."

"This simple test would, in my opinion, decide the whole question, for the very simple reason that these experimental platforms and trucks are the foundations which sustain all the superincumbent weight, and transmit it directly to the track underneath—whether this weight be in the form of additional length of platform, or of the superstructure of the car; or whether it be in the shape of paying freight and passengers."

"I maintain that the double truck flat, or platform car, is only an extension of these end platforms, properly connected together, and supported under the centre by a tension rod of iron; and that the box car, and the passenger and saloon coaches, are only these

very platforms and their extensions, sided up and covered over in a manner, and with a finish appropriate to their respective uses. And it is quite evident to my mind that this superstructure above the platform, which encloses the space required to protect the load, need be no heavier upon the wider gauge, than the proportion justly due to the increased tonnage, or number of passengers which it is designed to enclose and protect. If doubts exist upon this point, however, the matter may be very easily settled by extending the scope of the proposed experiment with the platforms, so as to include fully completed box and passenger cars, of the length, width, and height proposed for the respective gauges."

"But admitting, for the moment, that all the advantages claimed for the 3 ft. 6 in. gauge are, or appear to be, justly due to that gauge, I should still hold that, with the exception of the slight percentage chargeable to the wider gauge for additional cost of construction, all these advantages can be realised with greater economy and safety, by using the same character of rolling stock upon the 4 ft. 8½ in. gauge. And that these advantages, if realised upon the wider gauge, would far overbalance the additional cost of construction."

"It has been shown that the percentage chargeable to the additional cost of construction for the wider gauge is very small, probably not exceeding five to ten per cent. In order to adapt the rolling stock, which your chief engineer recommends, to the wider gauge, it would only require the lengthening of each axle 1 ft. 2½ inches. *And the weight of this extra length of axle and its cost I claim to be the only items which, under this arrangement, can justly be charged,* EITHER AS EXTRA DEAD WEIGHT, *or extra cost.*"

Having already proved, and I trust clearly, that the suggestions contained in the above paragraphs are utterly impracticable, and in reality tend only to show that General Buell's proposed rolling stock is adapted more nearly to the requirements of traffic than the ordinary wide gauge stock, I may briefly refer to the advantages which Mr. Seymour claims could be obtained by the adoption of narrow gauge stock for a broad gauge road.

These advantages are:—1. If commercial advantages are to be gained by exchanging cars with connecting lines, you would be in a condition to secure them. But I find that Mr. Seymour is an advocate of break of gauge for main lines, and to prove his case he advances the argument of General D. C. McCallum, for many years General Superintendent of the New York and Erie Railroad.

General McCallum states that, "It was also said that *uniformity of gauges* was necessary to the economical transportation of freight; and that a departure from the uniformity hitherto preserved would involve additional expenditure in loading and unloading freight, between all connecting roads having different gauges, as they would, from this cause, be precluded from interchanging cars; the disparity limiting their use to the particular road to which each was adapted.

"Plausible as this argument may at first sight appear, it is nevertheless, in point of fact, not true as to the *economical* effects claimed; as the cost of transferring freight from the cars of one road to those of another with which it connects, is less than that of hauling the 'empty returned cars' back—rendered necessary in cases where the freight is sent east—the preponderance of trade being largely in that direction. It may be said, the 'dead weight' hauled would be the same whether the load was conveyed in cars belonging to this or some other road; but such is not the case, as the cars belonging to this road may be used in transporting local freights on their return, between intermediate stations, so as to be partially loaded at least; whilst in the other case the cars must be promptly returned to their owners for use.

"This system of interchange of cars, so far as short roads are concerned, is undoubtedly beneficial; but if applied in connexion with long roads, the benefits will be found to be derived at the expense of the latter, as in the settlements between the two, the payments for 'mileage' for the use of cars will in-

variably be in favour of the short lines. The long roads by this system are frequently compelled to pay the hire of rolling stock of inferior construction (their own, perhaps, in the mean-time standing idle), and also to expend large sums to keep such cars in repairs; as they are not unfrequently sent from one road to another in such a dilapidated condition as to involve the necessity of switching them out of the train before reaching their station, making it often necessary to reship goods at points where it is not only inconvenient but expensive to do so. This has been the experience of this road, and our accounts show that it has *cost this Company nearly double the amount per mile run for the repairs of cars belonging to other lines that has been expended on their own.* These objections have been found so serious in their character that it has been deemed necessary to almost entirely discontinue the system of inter-change, although the lateral roads connecting with this were constructed of the same width of gauge with that particular object in view.

"Whatever advantages may be claimed for the system, in its application to short roads forming the same line, or to lateral roads connecting with main trunks, I have no doubt it can be clearly shown that companies owning the latter have nothing to gain, but much to lose, by such an arrangement; and I confidently believe that the experience of railroad managers generally will bear me out in the remark that a road five hundred miles in length, with a gauge that does not correspond with that of any independent line with which it connects, enjoys in this particular an enviable position.

"An accurate account of the cost of loading and unloading has been kept at the Dunkirk station, from which it appears the expense is about SEVEN CENTS A TON, certainly a much less sum than the cost of hauling the extra dead weight, repairs of cars, and wear and tear of machinery, involved by the inter-change of cars."

Without indorsing opinions which, however, have much to recommend them, I may point out that the cost of transferring goods involved by break of gauge is so small as to be of little consequence, although I believe all the opponents of broad gauge (with the honourable exception of Mr. Seymour) have strained this point to the utmost, and have endeavoured to show that the cost of shifting goods from one line to another would of itself more than counterbalance all the other advantages of narrow gauge. These thorough-going advocates forget that no traffic is conducted without a break of gauge, and that under the most disadvantageous conditions; for freight conveyed in horse wagons to depôt cannot be shifted upon the railway so quickly or so cheaply as it can from one railway train into another alongside of it. The large experience obtained upon this point is very conclusive, not only from the daily practice of transferring goods from road to railway at all our large depôts, but upon the many narrow gauge lines now working.

Thus on the Antwerp and Ghent Railway the maximum rate is 3·11d. per ton, on another Belgium narrow gauge it is 1·5d. per ton; on the New York and Erie it was found to be 7 cents; in Sweden 2d. a ton; on the Montepone line about the same, and M. Nördling has demonstrated that for a line with a very moderate traffic there is a marked economy in breaking gauge for a line only two miles in length, the saving increasing rapidly as the length of line and amount of traffic augment. But Mr. Seymour and myself are so thoroughly in accord upon this subject of break of gauge that I allude to it for the benefit of those who may have been influenced by the objection based on this point.

Mr. Seymour's second alleged advantage is: "A train, like a wagon, may be hauled much easier with wheels of large than small diameter. This width of gauge allows of considerably larger wheels, under its *ordinary* rolling stock, than are admissible upon the narrow gauge; but with this proposed reduced

height of car upon the wide gauge the wheels may be made so much larger that a very material saving will be effected in power." I must confess my inability to understand this "advantage." Does Mr. Seymour mean that he proposes to make a radical change in American rolling stock, and to substitute wheels of large diameter for the 30 in. wheels usually employed in the States? He must, I presume, mean this, as Mr. Pihl uses wheels of the same size for the Norwegian railways,* although the word "*ordinary* rolling stock" would lead us to suppose that he wishes to imply that the wheels of ordinary American rolling stock are larger than can be obtained on the 3 ft. 6 in. gauge. I believe, indeed, that the wheels of the Denver and Rio Grande Railway cars are only 24 in. in diameter, the object being to keep the lofty stock as near the rails as possible; and the Denver passenger cars being 10 ft. 6 in. high, to what "proposed reduced height" does Mr. Seymour refer, and how much larger would he make his wheels in one case than the other? I can only suppose that a gentleman like Mr. Seymour, bound entirely to precedent, would not propose any radical change—would in fact shrink from advocating anything existing only "in theory and upon paper," and that he must mean that a very material saving would be effected in drawing a car upon 30 in. wheels over a car running on 24 in. We may ascertain exactly how much this "saving" would be.

On a straight and level line the normal resistance of wagons is composed of two elements:—

1st. The friction of the wheels.

2nd. The resistance of the air.

When working at low speed the second element may be neglected, and the resistance considered as due only to the frictional resistance, which is expressed by the following well-known formula:—

$$R = (p + p')f' + \left(p \times f'' \times \frac{d}{D}\right)$$

* All my 3 ft. gauge stock has 30 in. wheels.

In which

p = the weight of the wagon without the wheels;
p' = the weight of the wheels;
d = the diameter of the axle journals;
D = the diameter of the wheels;
f' = coefficient of the rolling friction of the wheels;
f'' = coefficient of the friction of the axle journals in their bearings.

The coefficient $f' = 0{\cdot}001$ according to Wood, and by the experiments of Vuillemin, Guébhard, and Dieudonné, the resistance of a wagon moving at a speed of from 0·62 to 3·1 miles per hour = 2·464 lb. per ton (2,240 lb.), or nearly the same as that given by Mr. Wood. The coefficient $f'' = {\cdot}018$, for axle boxes lubricated with oil. (With grease lubrication $f'' = {\cdot}032$)

In the Denver and Rio Grande stock,

$p = 11{,}620$ lb.
$p' = 3{,}380$ lb.
$d = 3{\cdot}25$
D = 24

$$\text{then } R = 15{,}000 \times {\cdot}001 + \left(11{,}620 \times {\cdot}018 \times \frac{3{\cdot}25}{24}\right) = 43{\cdot}32.$$

The 24 in. wheels of the Denver stock would weigh 335 lb. each, and the weight of the 30 in. wheels would be 440 lb. (These are, I believe, the weights of the standard cast-iron wheels used in the States.) The difference of weight against the eight larger wheels would be 840 lb., the increased weight of axles (assuming the same section in each case) would be 224 lb. To this must be added the increased weight of the bogie frame due to the larger gauge; this would be equal to at least 1,000 lb., so that the increased dead weight of Mr. Seymour's proposed stock would be at least a ton. In this case we should have—

$p = 12{,}620$ lb.
$p' = 4{,}380$ lb.
$d = 3{\cdot}25$
D = 30

$$\text{then } R = 17{,}000 \times \cdot001 + \left(12{,}620 \times \cdot018 \times \frac{3\cdot25}{30}\right) = 41\cdot60$$

These resistances apply to low speeds; but the same holds good for any velocity, as will be seen from the following table of resistances formed by MM. Vuillemin, Guébhard, and Dieudonné :—

Speed in miles per hour.	Coefficients of resistance per ton (2240 lb.)
21·7	17·024
15·5 to 18·6	14·112
12·4 ,, 15·5	12·096
9·3 ,, 12·4	9·632
6·2 ,, 9·3	7·616
3·1 ,, 6·2	5·6
·62,, 3·1	4·48
Starting	19·488

This "very material saving" is thus only 4 per cent. of the total resistances at low speeds, while as the speeds increase the percentages diminish, until, as will be seen from the annexed table, at the very moderate speed of 20 miles an hour, it sinks down to ¾ per cent.

The carriage by which these results were obtained had a close body carried upon four wheels, the axles being lubricated with oil. It weighed 12,100 lb. It will be seen from the above figures that the resistances increase with an increase in the initial velocities; if the initial velocity is doubled, the resistances are almost doubled also.

Mr. Seymour's third alleged advantage is as follows: "Having a greater base of track in proportion to the height and width of your cars, the irregularities in the track would be less apparent; and you could certainly run as fast trains with greater safety, or faster trains with equal safety, than you could upon the narrow gauge." But in paragraph 24 we find that Mr. Seymour gives it as his opinion that there is no "reason why an engine of sufficient power will not haul a train with as great speed and

safety upon a narrow as upon a wide gauge." So that by his own showing there is no special advantage due to the modification he proposes.

Fourth advantage: "The height and width of the train being less than that in general use upon the wider gauge, the atmospheric resistance would be proportionately less; and you could make faster time with the same amount of power than is made upon the ordinary 4 ft. 8½ in. road."

Fifth advantage: "You would relieve the entire question, or, at least, the wider gauge portion of it, from the enormous load of extra *dead weight*, which it has heretofore been compelled by its adversaries to carry, because, under this arrangement, it would evidently be reduced to merely the weight due to the extra length of the axles."

The proposition of Mr. Seymour to place narrow gauge stock upon a broad gauge track proves clearly that the advantages claimed by me for narrow gauge are indisputable, so far as rolling stock is concerned. He admits all, in fact, that I could wish him to admit, the reduction of dead weight, and the construction of vehicles, the size of which shall be adapted to the loads they shall have to carry, and as he has already stated his belief that safe running at high speeds is equally practicable on both broad and narrow gauge, it appears to me that he must be a strong narrow gauge advocate without knowing it himself, otherwise how could he help me to prove my case so well as he has done?

In a few words I may dismiss this question of narrow gauge stock on broad gauge under-frames. By adopting it he would gain nothing, and would lose much. According to his own statement, he gains nothing in safety or in capacity, while he loses enormously in first cost of building his line, as I have already shown; he runs up his dead weight, and requires heavier, more powerful engines to do the same work that can be better performed upon narrow gauge. Even the strong argument of

avoiding break of gauge he refutes himself, by showing it to be a mere fallacy. But even if everything else were equal, it is obvious that the large saving in first cost of construction is sufficient to place his proposal outside the pale of professional civilisation.

Paragraphs 42 to 44.—"If other reasons were wanting, I believe that those already given would fully justify the expenditure of the very small percentage of additional cost; and also the hauling of the very small additional amount of *dead weight* which would be fairly chargeable to this arrangement.

"I have not deemed it important to notice particularly that portion of your chief engineer's report in which he compares the 3 ft. 6 in. with the 3 ft. gauge; neither have I paid any attention to his statements, figures, and illustrations, respecting the size, weight, and proportions of engines, cars, iron rails, &c., or to the centre of gravity, angle of stability, and laws of equilibrium, &c., &c., for the reason that I prefer that the advocates of all these extreme narrow gauge theories upon different gauges, should settle these details among themselves; and also for the further reason that, if my conclusions are right, and theirs are wrong, in relation to the general principles which lie at the foundations of the entire narrow gauge theory, then these details are, comparatively speaking, of very little consequence.

"I will venture the remark, however, in passing, that if the comparisons which your chief engineer institutes between the 3 ft. 6 in. and the 3 ft. gauges are well founded, they would not only go very far towards weakening his argument against the 4 ft. 8½ in. gauge; but they would, if carried sufficiently far, be in great apparent danger of destroying the prestige claimed for the little Festiniog road in Wales."

In designing the rolling stock for the Norwegian lines, Mr. Carl Pihl adopted such proportion as to get almost the same angle of stability as is obtained in ordinary lines of 4 ft. 8½ in. gauge.

The angle contained between lines drawn from the centre of gravity of an ordinary American car to the rails 4 ft. 8½ in. apart is less than that obtained in the ordinary Norwegian 3 ft. 6 in. stock,

which varies from 40½ to 38½°, according to the position of the load, and these are obtained with wheels 30 in. in diameter.

Paragraphs 45 to 54.—"Your chief engineer has omitted to urge one argument in favour of narrow gauge railroads which is generally urged with great pertinacity by the advocates of that theory, although he fully endorses the principle. I refer to the advantage claimed for passing through curves. He says: 'I concede the 3 ft. gauge has an advantage in turning acute curves; but this is no argument; for, whatever might be the gauge of the track, I should locate the line of road as straight as possible, at the same time giving the question of economy due consideration.'

"Now, I respectfully submit that, if the narrow gauge has the advantage claimed for it in this respect, it is a very strong argument in its favour, for the reason that the maximum load which can be hauled over any railroad with a given amount of power is, with the present arrangement of machinery, governed as much by the increased resistance upon its curves as by the increased relative resistance upon its grades. And, therefore, if this resistance upon curves is less upon the narrow than it is upon the wider gauge, it certainly is entitled to the full benefit of the argument.

"But I believe this argument, like most of the others advanced in support of the narrow gauge theory, to be entirely fallacious.

"There are two kinds of resistances which a curve imposes upon an engine and train while passing through it, that are not encountered upon a straight line. One of these is the impingement of the flange of the wheel upon the outer rail, while overcoming the direct, or tangential tendency of the train; and the other is the sliding of the wheels upon one rail a distance equal to the difference in the lengths of the two rails throughout the curve.

"The resistance due to the impingement of the flange against the rail is greatest upon curves of the smallest radii, and naturally diminishes as the radius increases, for the reason that the angle of impingement becomes less. Now, with a centre line of given radius, it is evident that the farther the outer rail of the curve is removed from this centre line, the greater will be the radius of the curve of the rail upon which this resistance occurs; and hence, the wider the gauge, the less will be the resistance.

"The amount of extra power required, at any one time, to overcome the resistance caused by the sliding of the wheels which sustain one half the load, may be regarded as the same upon one gauge as the other; although the length of time during which, with a given rate of speed, this extra power must be exercised, is in proportion to the difference in length of the outer and inner rails of the curve; and this difference will, of course, be slightly in favour of the narrower gauge.

"During the discussion of the gauge question before the Erie Company, the opinion of Mr. Robert Stephenson, as given before the Parliamentary Commission, was quoted by the advocates of the narrow gauge, to prove that the resistance was greatest upon curves of the wide gauge.

"The following question was put to Mr. Stephenson by the gauge commissioners: 'Is the lateral friction greater with one gauge than with the other?'

"Answer by Mr. R. Stephenson: 'Any lateral friction that arises must be greater; for it arises from the angle of the wheel against the line, and it must be greater with the wide than with the narrow gauge.'

"This proposition was answered, and its error demonstrated so effectually, by Mr. S. S. Post, who was then acting as engineer and superintendent of the eastern division of the road, that I shall take the liberty of appending his argument for your information."

The advantages which the narrow gauge possesses with regard to curves are as strongly marked in the construction through difficult countries, as in subsequent working of the traffic. The reduced wheel base of a narrow gauge carriage renders the working of curves practicable, which would be utterly impossible on the broad gauge. And with the adoption of curves of small radius necessarily follows considerable saving in construction of a line.

I may add here a few words upon the effect of curves upon the resistance of trains. The resistances they offer depend chiefly upon the nature of rolling stock employed, and in a less degree upon the radii of the curves, the elevation of the outer rail, and

velocity. With properly adjusted curves, and suitable rolling stock, trains should traverse curves with no special resistance. The combination of circumstances required to produce such a result would be: first, that the axles should be constantly radial to the curve; second, that the wheels on each axle should revolve independently of each other, or that running fast on their axles the outer wheel should be enlarged in proportion as the outer rail is curved with a larger radius; or, third, that the safer elevation of the outer rail must be such that the transverse inclination of the line must give a gravitating tendency inward to counterbalance the tangential force at any given speed. The centrifugal force in terms of the weight of a body moving in a circular path is $= \frac{L\, v^2}{32\, r}$, in which

L = load.
v = velocity in feet per second.
r = radius in curve in feet.
32 = accelerating force of gravity.

So that if with a given load, moving at a given speed, round a curve of a certain radius, the centrifugal force $= \frac{1}{10}$ L, the transverse inclination of the track should be 1 : 10 so as to give a corresponding tendency to gravitate towards the centre of the curve.

Could the conditions above-named be fulfilled, the passage of curves laid upon any gauge would offer no more resistance than that due to the passage of straight lines. But this is obviously impossible; the axles are not maintained radial to the curve, therefore the wheels upon the outside or longest path of the curve must slip, and reacting the flanges must impinge against the rail, while superelevation can be adjusted only to suit one speed, which, if exceeded, will drive the flanges hard against the outer rail, and which, if not attained, will result in grinding them against the inner rail.

The long and rigid wheel base inseparable from ordinary four-wheeled stock (with the bogie the case is altered) is totally unsuited for passing round sharp curves, and causes by far the

largest proportion of the curve resistance. But then resistances practically diminish inversely as the square of the wheel base, so that it is evident the narrow gauge stock possesses a great and indisputable advantage over the larger. Thus a carriage with a 12 ft. wheel base throws four times the strain upon the rails that would be caused by a 6 ft. wheel base, because the versed sine corresponding to such chords as those of which we have been speaking is practically four times that corresponding to a 6 ft. chord on the same curve.

With regard to the other cause of resistance, the slipping of the wheels upon the outer rail, let us assume the case of a 200 ton train travelling at the rate of 20 miles an hour, meeting a curve of 10 chains radius, and extending through the eighth of a complete circle, the gauge being 4 ft. 8½ in., and the inner rail having a curve of 10 chains. The difference in length of the inner and outer rails with any gauge upon any curve $= 3{\cdot}141 \times 2\,G$ (G being the gauge) for a complete circle, and in the case we have assumed of a curve one-eighth of a circle, the extra length of the outer rail would be 3·7 ft., over which the wheels must slip, supporting one half the weight of the train. Taking the coefficient of sliding friction at 1-5th, there would be 20 tons = 44,800 lb. of resistance passing over 3·7 ft., and developing 165,760 foot pounds of work; but the mean length of the curve being 520 ft., the time occupied in traversing it at the speed indicated would be 20 seconds, and the extra work expended, $\frac{165{,}760 \times 3}{33{,}000} = .15$ horse-power. On a 3 ft. 6 in. gauge the reduction in the length of the outer rail and dead weight of train would reduce this extra power to at least half. As the radii of the curves diminish the resistances increase, but the time taken in passing around them is reduced also, so that the increased power is required for a shorter period, and although narrow gauge offers, as we have seen, far less resistance due to the slipping on the outer rail, and consequently causes less wear both to wheels and rails, the most

important point to be considered is the minimum radius which can be adopted on narrow and wide gauge; and it will be found that the former has a marked advantage over the latter. I have already shown that it is impossible to reduce the wheel base of ordinary rolling stock to the dimensions which narrow gauge allows, and I have mentioned that the resistances practically increase as the square of the length of the wheel base. It is obvious, then, that in this respect narrow gauge complies more closely with the desired conditions, and as reduced resistance is synonymous with prolonged life of rails and of rolling stock, I think it is evident that the sharp curves narrow gauge admits of, have no small balance of advantage.

Paragraphs 55 to 65.—"I have thus given you, at some length, my views in relation to the recommendations of General Buell, your chief engineer, as contained in his report; and I fear that these views, in some instances, may have been expressed more frankly, and with greater candour, than may prove to be entirely agreeable either to yourself or to him.

"I was educated, as you are aware, in the Broad Gauge School, having spent the early portion of my professional life upon what is now the Erie Railway, and its branches and extensions, of which company you were at that time an active and prominent director. You can, therefore, make such allowances as you may think proper, for early prejudices, in what I have said or may say upon this subject. I am not conscious, however, of entertaining a feeling either of prejudice or of interest in the matter, my only desire being, if possible, to arrive at the truth.

"You have done me the honour to ask for my written opinion: 'as to whether a first-class railway, of equal speed, comfort to passengers, and capacity for freight, with those possessed by the gauges now in general use, can be built upon a narrow gauge; and if so, what gauge would you recommend?'

"In discussing a question of this importance it should be borne in mind, that the general adoption of the 4 ft. 8½ in. gauge, both in this country and in Europe, is not the result of accident, or the want of careful study and investigation.

"When Mr. George Stephenson first conceived the great idea of adapting locomotive steam power to purposes of railroad trans-

portation, it is true that the controlling idea of his practical mind was, not so much the establishment of the most useful and economical gauge, as it was the substitution of steam for horse power; but the roads, and the wagons upon and to which this new motive power was to be applied, had already been constructed of the 4 ft. 8½ in. gauge; and a long experience had shown them to be the best and most economical that could be devised for the use of horse power. Mr. Stephenson found no difficulty in adapting his machinery and power to that gauge; and he therefore adopted and advocated it during his long and eventful life. It therefore very soon became the ruling gauge of England; and, as the first locomotives that were used in the United States were manufactured in England, it very naturally became the ruling gauge in this country.

"At a subsequent period, the subject of gauges underwent a most searching investigation in England, by a parliamentary commission, before which Mr. Brunel and other distinguished engineers advocated a gauge of much greater width, while Mr. Stephenson and others adhered to the original gauge of 4 ft. 8½ in.; and this gauge was finally approved by the commission.

"At a still later day the question of gauges was thoroughly discussed by some of the best engineering talent in this country before the New York and Erie Railroad Company; and that company, being composed of some of the most practical and enlightened men in this city, after hearing the most exhaustive reports and arguments upon the subject, decided to adhere to the gauge of 6 ft., which had previously been adopted.

"At another time the Legislatures of New Jersey and Ohio passed laws establishing the gauge of railroads, in their respective States, at 4 ft. 10 in., for the purpose, it is believed, of preventing an interchange of rolling stock between their own roads and those of adjoining States. This restriction, however, if not repealed, has been in a great measure superseded by the very questionable, if not dangerous device, of the *broad-tread* or *compromise* wheel, which allows the same car to run over both the 4 ft. 8½ in. and the 4 ft. 10 in. gauges.

"In many of the Southern States, and also in Canada, gauges of 5 and 5½ ft. have been adopted to a great extent, and used successfully during many years.

"The original charter of the Union Pacific Railroad Company provided that the President of the United States should decide

upon the width of gauge for that road. Being then in the employ of the Government, at Washington, I was requested by the Secretary of the Interior to recommend a gauge to be adopted by the President. I accordingly recommended the 5 ft. gauge, which was approved. Congress, however, changed it afterwards, by special resolution, to 4 ft, 8½ in.; the argument urged in favour of the change being, that all eastward connecting railroads were of that gauge; and it would therefore be fatal to the enterprise, to make a break of gauge at the Missouri River.

"In view of all these facts, it must be conceded that a great deal of thought, investigation, experience, and legislation have already been bestowed upon the subject; but in no instance, so far as my knowledge extends, has the idea been seriously entertained or advocated, of reducing the gauge of main trunk lines of railway below the limit of 4 ft. 8½ in., until the present agitation of the subject has given prominence to that idea."

I have reproduced these paragraphs, rather because they contain one or two interesting facts in railroad history, than for their reference to the subject under discussion, but I may point out that the assertion made by Mr. Seymour, that Mr. George Stephenson "first conceived the great idea of adapting steam power to purposes of railway transportation," is a very characteristic one, and illustrates that he is as careless about facts as he is incorrect in many of his deductions.

Paragraphs 66 *to* 71.—"And now, if this theory of extreme narrow gauges for all classes of railroads shall prove to be well founded, it certainly becomes us to look about, and see whether the same radical error has not crept into our other methods of locomotion, transportation, and the various applications of natural and mechanical power. Whether our heavy draft horses, and clumsy carts and wagons could not profitably be exchanged for a greater number of the more diminutive Shetland pony, with carriages to fit; or, perhaps, for something approaching still nearer to our single tracked wheelbarrow or velocipede. Whether our State canals should not have been made narrower instead of wider. Whether the streets in the lower portion of our city should not be diminished instead of enlarged in width. Whether our steamers and sailing vessels should not have retained their original dimensions, instead of growing to their present enormous proportions.

Whether five hotels had not better be constructed, with accommodations for one hundred people each, instead of one single hotel with accommodations for five hundred people. And whether twenty stationary engines of five-horse power each had not better be employed to do the work of one single engine of a hundred horse power.

"It is certainly important that these vital principles should be thoroughly examined; and if it shall be found that we have been living, during the past half century, under a radical mistake or illusion, it is high time that the mistake should be corrected, and the illusion dispelled.

"It is quite evident, to my own mind, that this entire subject of railway gauges has become too much confused and befogged by technical phrases, scientific terms, and glittering generalities. When stripped of these, it becomes simply a question of sound judgment, and good, strong common-sense.

"Every intelligent farmer understands that a load of hay will tip over easier than a load of stone, simply because it is more *top-heavy;* but if you put your 'centre of gravity,' 'angle of stability,' and 'laws of equilibrium' at him, he will become confused at once.

"Every intelligent teamster, or carter, knows that he can haul a given quantity of tonnage a given distance, cheaper, if not quicker, by using a good, strong double team with one suitable wagon; instead of by hauling, with the same team, two wagons of half the capacity each, one behind the other; or instead of dividing his team, and attaching one horse separately to each of the smaller wagons; simply because, in the case of the two smaller wagons, one behind the other, he had twice the number of axles to grease, and their friction to overcome; and at least one-half of his load is too far behind his team to be handled easily; and in the case of two single horses hitched to two smaller wagons, he not only has twice the number of axles or journals, but he has an extra driver to pay; but if you should put the *dead weight* and extra power arguments at him with all their force, ten to one he would not understand a word you might say.

"And still the great principles which underlie and should govern the construction and management of railroads, are simply these, or others, equally practical in their application, and nothing more."

There is little to observe upon these paragraphs; Mr. Seymour's whimsical suggestion to reduce the dimensions of our streets, vehicles, vessels, hotels, and so forth, is totally beside the question, and, indeed, he has previously stultified himself by suggesting the very alteration—namely, the reduction in size of vehicles, which he afterwards ridicules.

And if his friend, "the intelligent teamster," had only a load for half the capacity of his "good, strong, double team, with suitable wagon," and that for forty out of fifty times his "good, strong, double team, with suitable wagon," only carries 25 to 50 per cent. of its capacity, what then would the intelligent teamster do? Why at the end of six months, if he found himself still out of bankruptcy, he would have divided his "good strong, double team, with suitable wagon," into two, each one of sufficient capacity to take his *mean average*, and trust to sending a second wagon on the few occasions when it happened that he had more than his average load to take. Mr. Seymour assumes his teamster to be the reverse of intelligent, if he imagines he will run the two smaller wagons with a load insufficient for one of them.

Paragraphs 72 to 111.—"Applying these principles, as well as I am able, to the specific question of gauges now under consideration; and availing myself of a somewhat extended and varied experience, both in the construction and management of railroads, I am forced to the conclusion, that a first-class railroad cannot be constructed and operated with a gauge narrower than 4 ft. 8½ in., that will, if doing a large and miscellaneous business, combine all the elements specified in the interrogatory contained in your letter—to wit, 'equal speed, comfort to passengers, and capacity for freight'—with as much facility and economy as the same elements can be combined upon the 4 ft. 8½ in., or even a broader gauge.

"The subject, as presented to my mind, has naturally divided itself into the following general propositions:—

"1. Comparative cost of construction.

"2. Comparative facility and economy in packing or loading.

"3. Comparative economy in hauling.

"4. Comparative advantages of a gauge common to connecting lines.

"As to the first proposition, I am prepared to admit that the advantages are slightly in favour of the narrow gauge, but to nothing like the extent claimed by the advocates of the extreme narrow gauge theory.

"As to the second proposition, I claim that the advantages are so greatly in favour of the wider gauge, that they very far outweigh the additional cost of construction.

"I believe that the width of rolling stock, adapted to the 4 ft. 8½ in. gauge, can, if proper study and care are used in details, be constructed cheaper and of less weight, in proportion to its comfort and capacity, than rolling stock of the same relative width, strength, durability, comfort, and capacity can be constructed, and run with equal speed, economy, and safety upon a narrower gauge.

"The comparisons that are constantly being made by the advocates of the extreme narrow gauge theory, between the weight and capacity of the rolling stock required for their favourite gauges, and that now in general use upon the wider gauge railways, both in this country and in Europe, is exceedingly unjust towards the broader gauge; for the reason that the extreme minimum of cost and weight has been studied and appropriated for their own gauges; and every inch of space is assumed as being occupied *during the entire trip with live or paying weight;* while, for the wider gauges, they adopt for the comparison a miscellaneous outfit, made up with strict regard to these elements of cost and weight, and used promiscuously for way and through business—sometimes full, sometimes partially loaded, and sometimes entirely empty, according to the nature of the traffic, or the circumstances which control the business of the road.

"They seem to imagine that all these contingencies would be avoided upon the narrower gauge, even if it were doing the same kind of business.

"But let the test, which I have suggested in another place, be fairly applied to this question, and I am perfectly content to abide the result.

"I am prepared to admit that a great deal of unnecessary and non-paying weight, as well as useless and injurious friction, are constantly being hauled over our railroads. And I trust that

the ventilation which this subject is now undergoing will have a tendency to correct this particular evil, even if nothing better shall result from it. I might illustrate this proposition by referring to the enormous and unnecessary weight of some of our passenger, drawing-room, and sleeping cars, in proportion to the number of passengers which they accommodate. Many of these are nearly as heavy as the engine that hauls them; and they are often obliged to be coupled as near the engine as possible, in order to be moved at all.

"I cannot admit, however, that this evil is in any degree chargeable to the width of track. It results entirely from the excessively *broad gauge* of the managers of some of our railways; and of the caterers to the public taste, who are allowed to come between the public and the stockholders who construct the road, and furnish the power to haul these cars; and this evil would be as likely to occur upon one gauge as another."

I need scarcely refer to the conclusions at which Mr. Seymour has arrived, because I have already discussed them so fully, and I hope I have shown that those advantages claimed for narrow gauge really exist to the full extent which I maintain for them. And I have not, it will be observed, assumed those special and unfair conditions of which Mr. Seymour complains; on the contrary, I have supposed the traffic conditions to be alike in both cases.

"As to the third proposition, with reference to the comparative cost and application of locomotive power upon railways of different gauges, I will respectfully refer you, for actual results upon the 6 ft. gauge, to the appended extract from General McCallum's Report, upon the New York and Erie Railway; and for actual results upon the 4 ft. 8½ in. gauge, to a communication which has been kindly furnished me by Mr. H. Stanley Goodwin, Assistant-General Superintendent of the Lehigh Valley Railroad, which will also be found in the Appendix. But, for the narrow gauges, I can, unfortunately, refer you only to *theoretical* and *assumed* results; and I do not regard these as being sufficiently reliable, either to warrant a comparison with known results upon the broader gauges, or to justify any conclusions that might result from such a comparison.

"From General McCallum's Report it appears:

"1. That an engine of 66,050 lb. total weight, and having 40,050 lb. weight upon the driving wheels, hauled a train consisting of 100 loaded cars, weighing 3,423,150 lb., over a mile of road, on an ascent of 6·14 ft., and a curve of 5,730 ft. radius, in 11½ minutes.

"2. That the same engine hauled a train of 22 loaded cars, weighing 753,082 lb., over a mile of road, on an ascent of 60½ ft., and a curve of 1,146 ft. radius, in 6½ minutes.

"3. That the same engine hauled a train of 25 loaded cars, weighing 870,250 lb., over one mile of road, on an ascent of 52 ft., and a curve of 1,146 ft. radius, in 9 minutes.

"4. That the same engine hauled a train of 23 loaded cars, weighing 800,330 lb., over one mile of road, on an ascent of 60 ft., and a curve of 1,637 ft. radius, in 5 minutes.

"5. That the same engine hauled a train of 24 loaded cars, weighing 821,544 lb., over one mile of road, on an ascent of 60 ft., without curvature, in 5½ minutes.

"6. That the same engine took the same train up the next mile, on a grade of 58 ft., and through a curve of 3½° per 100 ft., in 8½ minutes.

"It appears from Mr. Goodwin's letter:

"1. That the engines in ordinary use upon the Lehigh Valley Road are of two kinds: 1st, the ordinary 10 wheel engine, weighing from 76,400 lb. to 78,000 lb. with fire and steam, of which from 61,600 lb. to 63,000 lb. weight is on the 6 drivers, and the remainder upon the leading truck; 2nd, the other kind of engines called 'Consolidation,' weigh 86,000 lb. with fire and steam, of which 76,000 lb. is on 8 drivers of 4 ft. diameter.

"2. That the average weight of freight cars, in general use upon that road, is $3\frac{4}{10}$ tons each, and that the average useful load which they carry is $5\frac{4}{10}$ tons each, making $8\frac{8}{10}$ tons of car and load." *

But this useful load is only carried in one direction, making the paying load per mile run by the wagons not $5\frac{4}{10}$ tons, but $2\frac{7}{10}$ tons.

"3. That the heaviest traffic upon that road is upon 46 miles, where the grade is either level, or descending at the rate of 20 ft. per mile, and that upon this portion there are many curves of 955 ft. radius.

"4. That upon this portion an engine can haul down, with the

* Please note here the discrepancy between *facts* and *assumptions*.

same ease, the number of loaded cars that the same engine will haul up empty.

"5. That this number averages in good weather 150 cars, hauled with the 10 wheel engines, and in some cases has reached 200.

"6. That the 'Consolidation' engines have hauled 250 cars over the same road, 'and could probably exceed 300 before reaching the engines' capacity.'

"7. That upon 12 miles of another portion of the road there is a grade of 96 ft. per mile, with curves of 955 ft. radius. Up this grade the 10 wheel engines haul 22 loaded cars, weighing 194 tons; and the 'Consolidation' engines haul 33 loaded cars, weighing 290 tons.

"8. That upon an ascending grade of 146 ft. per mile for 2 miles in length, the 10 wheel engines haul 37 empty cars, weighing 122 tons, and the 'Consolidation' engines haul 55 empty cars, weighing 182 tons.

"The foregoing synopsis of general results contains, perhaps, all the information upon this point that is required for the purpose of instituting a comparison between the relative cost of power upon the 6 ft. and the 4 ft. 8½ in. gauges respectively; and also to deduce a result which would logically follow, upon a comparison between the 4 ft. 8½ in. gauge, and the narrower gauges.

The information contained in these paragraphs is interesting as affording some particulars as to the duties of certain engines at work in the States, but nothing more.

"But I will leave the labour of such a comparison to be performed by the advocates of the extreme narrow gauge theory, and close what I have to say upon this branch of the subject with the single remark, that until this is satisfactorily done or until such other practical tests are applied to the narrow gauges as will demonstrate, beyond a question, their superiority in this, as well as in the other respects referred to, they should not expect, with so much apparent confidence, that their favourite system will soon supersede the one which has been in use so long and so successfully.

"As to the fourth proposition, with reference to continuous gauges, it being more of a commercial than an engineering question, I would not speak with so much confidence, although I

should, at the present time, and under all the circumstances, probably recommend the 4 ft. 8½ in. gauge as the standard gauge of the country. I have never been an advocate, however, of continuous gauges upon main trunk connecting lines of railway, merely for the purpose of avoiding the necessity of changing cars and breaking bulk.

"I believe that the great damage and inconvenience growing out of an interchange of cars upon thousands of miles of connecting, and in many instances hostile or competing lines, very often overbalance any good, or real saving to the stockholders, that may result from it; although, like all other rules, it probably has its exceptions. If the truth could be ascertained, I have no doubt that the present mania for harmonising gauges, and consolidating lines, is more the result of a desire, on the part of ambitious managers, to overreach competing lines, by the establishment of agencies and other influences very far in advance of them, than any saving in the actual cost of transportation that, as a general rule, can be shown to result from it.

"Inasmuch, however, as the opinion of a practical railway manager of high reputation, and of a much larger experience in such matters than my own, should have much greater weight than any that I would venture to advance, I will append an extract from a very able and comprehensive report made in 1856, to the New York and Erie Railroad Company, by General D. C. McCallum, then general superintendent of that road, and afterwards, during the late rebellion, the general manager of all the military railroads in the United States; and as the same report contains, in the same connexion, important facts and arguments bearing upon the subject now under consideration, relative to the application of power, the comparative economy of transportation upon different gauges, and the relation which the width of the gauge should bear to the amount of business to be done, I will also take the liberty of embodying these in the extract, for your information."

In these remarks I entirely concur with Mr. Seymour.

"Having expressed an opinion so decidedly against *all* gauges of a width less than 4 ft. 8½ in., it will probably be regarded as supererogatory for me to furnish an answer to the concluding

part of your question, to wit, 'and if so, what gauge would you recommend?'

"I trust, however, that I may be permitted to state the reasons which influenced me in recommending the gauge of the Union Pacific Railroad and its branches to be established at 5 ft.

"I believed then, and now believe, that experience has demonstrated that the width of rolling stock in general use upon the 4 ft. 8½ in. gauge is none too wide to afford the necessary and proper comfort to passengers, and stowage capacity for the average ruling classes of freight that are generally offered for transportation to the main trunk lines of railroad in this country. I also believe that the gauge of 4 ft. 8½ in. has been found somewhat too narrow to afford the requisite base for this width of rolling stock, to insure a full measure of economy and safety, particularly if run at high rates of speed over our somewhat imperfect and uneven railroad tracks.

"This disproportion between the widths of gauge and rolling stock has undoubtedly grown out of an effort on the part of the 4 ft. 8½ in. gauge managers to reach, as nearly as possible, the width of freight and passenger cars used upon the wider gauges of 5½ and 6 ft., and thus afford (approximately at least) the same 'comfort to passengers and capacity for freight' that are claimed for these wider gauges. In doing this, I think they have slightly overreached the verge of safety, if not of strict economy; and therefore, a gauge of 5 ft., placed under the same rolling stock, would, to some extent, correct this error. Inasmuch, therefore, as I then believed that the great pioneer line, extending from the Missouri River to the Pacific Ocean, would, for many years at least, have no competitor; and that it could, therefore, very well afford to run and control its own rolling stock; and that other Pacific lines, when built, would, in all probability, follow its example, I had no hesitation in recommending the 5 ft. gauge.

"The foregoing may be regarded as only a demonstration, based upon general principles, of the fallacy of the extreme narrow gauge theory, as applied to all main trunk lines of railway in this country.

"When these principles are applied particularly to the proposed Texas Pacific Railroad, I think they will be found to possess peculiar force.

"Your road, when completed, will necessarily come into direct competition, for the great trans-continental traffic, with the Central, Union, and Kansas Pacific Railroads, which are already constructed; and which, with their numerous connexions eastward of the Missouri River, form continuous lines from the Pacific Coast, at San Francisco, to the great commercial ports upon the Atlantic seaboard.

"The Northern Pacific Railway is now under construction, from Puget Sound, upon the Pacific, to our great inland lakes, and thence by numerous connecting lines to the Atlantic coast. And it will therefore very soon become another formidable competitor for this immense traffic.

"The Canada Pacific Railroad will also, in all probability, very soon be constructed, and form a continuous line from Puget Sound to the head of deep ocean steam navigation upon the St. Lawrence River at Quebec; thus forming another competitor for the traffic across the continent.

"These great competing lines will all have an unbroken gauge of 4 ft. 8½ in. throughout their entire length, from ocean to ocean.

"I would, therefore, regard the commercial argument in favour of an unbroken gauge, of at least equal width, for the Texas Pacific Railroad, extending, as it will, from San Diego on the Pacific to the Mississippi River, and thence with its connexions, eastward to the Atlantic Ocean, as being entirely unanswerable—not upon the ground that it can be defended upon strictly scientific and abstract principles; but for the more practical reason, that this theory of *funding* gauges, as well as stocks, has become the popular and settled policy of the country, with reference to our great competing lines of railway; and as such, is looked upon with favour, not only by those who furnish capital to construct these lines, but by those who provide business for them after construction.

"If, therefore, the construction of your road should be undertaken upon an inferior gauge, and one that would necessarily form a break with all its railroad connexions east of the Mississippi River, I should very much fear that capitalists would hesitate to furnish the means required for its construction; and that, if constructed, the travelling public, as well as the heavy freighting interests of the country, would discriminate largely against it.

"Thanking you for the confidence which you have manifested

in my opinion upon a subject of this magnitude, and hoping that the views herein expressed may aid you to some extent in arriving at a correct conclusion upon a matter so important to the ultimate success of the great enterprise which you have in hand,

"I have the honour to remain,

"Yours very respectfully,

"SILAS SEYMOUR."

I think there is little more to add upon these concluding remarks of Mr. Seymour. His admission that the present class of rolling stock is antagonistic to economy is, as I have said before, one that I am pleased to see him make, and I have little doubt that he will ere long complete the course of conviction he has so honestly commenced.

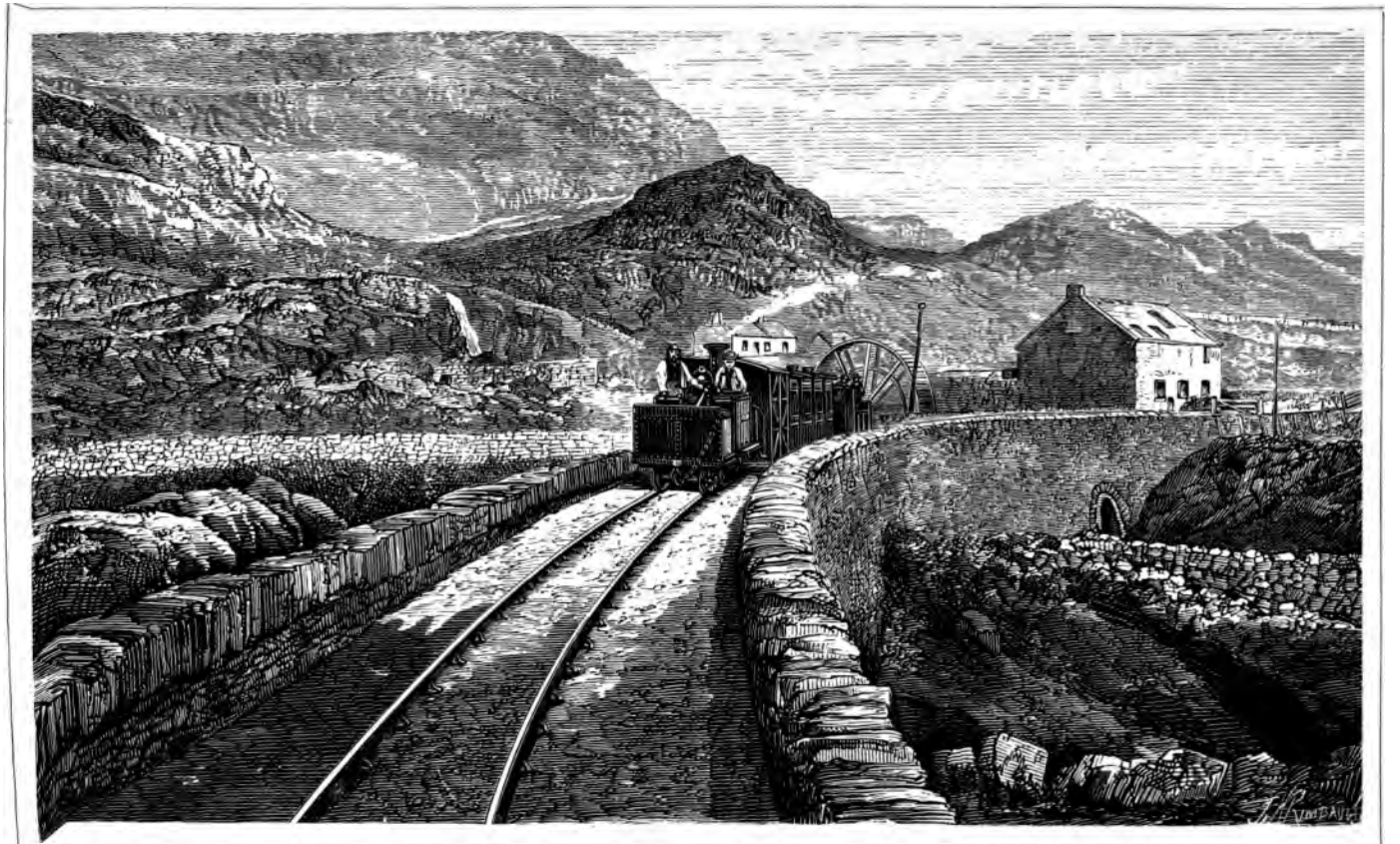
I cannot do better now than refer briefly to some of the leading narrow gauge railways now at work, in order that my readers may have the opportunity of forming a definite opinion for themselves upon existing facts, and first I may refer to the following interesting and very complete description of the Festiniog Railway, published in ENGINEERING on the 29th December, 1871:—

"So much has at different times been written concerning the celebrated Festiniog Railway, that there are probably but few of our readers who are not familiar with the general characteristics of the line, while there are doubtless a considerable number who have visited it in person. Notwithstanding this, we believe that the series of three views (taken from photographs) of different parts of the line, which we publish on the present and opposite page, will be regarded with much interest. To those who have examined this miniature railway the views may serve as reminders of a pleasant visit, while to those who have not inspected the line personally the sketches will, we trust, serve to convey a more clear idea of some of its features than they could derive from any mere written description. Before saying anything more concerning these particular views, however, it may be desirable that we should—even though we

necessarily reproduce some information previously published—give a general account of the Festiniog Railway and its rolling stock.

"The Festiniog Railway, then, is a single line of 1 ft. 11½ in. gauge, extending from the shipping port of Portmadoc to some slate quarries at Dinas, in the neighbourhood of Festiniog. Its length is 13¼ miles, exclusive of a branch about a mile long leading to Duffws. In the 13¼ miles the main line rises 700 ft., the rising gradients being continuous, but variable. For the first mile, indeed, from Portmadoc, the line rises very slightly, the portion on the Traethmawr embankment, which extends across the mouth of the river at Portmadoc, being practically level, as the inclination is but 1 in 1,343½. Exclusive of this flat portion of the line, the least gradient is 1 in 186, while the steepest is 1 in 68·69. The steepest gradient of any great length, however, is one of 79·82, which extends for about 2½ miles, while there is another of about the same length, of 1 in 85·22, and one about 2 miles long of 1 in 82·71. For a length of 12¼ miles the average gradient is 1 in 92.

"Traversing a rugged but most picturesque tract of country, now creeping along the steep hillside hundreds of feet above the valley below, now crossing deep ravines on narrow embankments, or rather walls of dry stone masonry, some of them 60 ft. in height, and then again threading its way through cuttings in the rock, only to burst out anew into the open and disclose a fresh panorama to the view, the line presents ever changing features of interest alike to the engineer and to the tourist. Throughout almost its entire course the line is a series of curves varying in radius from 8 chains to as little as 1¾ chain, some of the curves of the latter radius being 200 ft. in length. The curves are all of the parabolic class, and have been laid out with great care, the extremities being eased off into the reversing curves or straight lines, and as a result the entrance of a train into a curve, or its passage from one curve to



VIEW BELOW TAN-Y-GRISIAU.

another, is practically imperceptible. We know that there are some of our readers who will accuse us of exaggeration in making this statement; but we are certain that they will not include amongst their number any who have visited the Festiniog line itself. We must own that before we travelled over the line personally we ourselves regarded with a certain small amount of incredulity the accounts which reached us of the extraordinary ease and steadiness with which the curves were traversed on the Festiniog Railway; but having experienced that ease, it is only fair that we should atone for our early want of faith by adding our testimony to that of others. The result is, no doubt, due primarily to the adoption of the parabolic form for the curves; but its attainment also in no slight measure depends upon the admirable condition in which the permanent way is maintained—a condition of which we shall have something more to say presently—as well as upon the narrowness of the gauge and the wheel base of the rolling stock.

"The width of the line on embankments is 10 ft. at formation level; but in many of the cuttings there is a width of but 8 ft., and the clearance between the rock and the sides of the engines is excessively small. In the tunnels—of which there are two on the line, one 60 yards, and the other 730 yards in length—it is, if possible, still closer work, and in fact these tunnels, as they at present stand, form a complete bar to any further enlargement of the rolling stock. The shorter tunnel passes through a slate formation, while the longer one, which is partly on a gradient of 1 in 85·22, and partly on one of 1 in 116·59, is cut through syenite. Neither of the tunnels is lined. A prominent feature on the line are the dry stone walls or embankments to which we have already referred. The engraving taken in the neighbourhood of Tan-y-Grisiau station shows a train passing over one of these walls, although it scarcely gives a fair idea of the narrowness or height of the latter. The view to which we have referred is taken at a point

where the line formerly followed the contour of the hillside, making a deep bend, as shown on the left of the sketch. By the construction of the embankment, however, this detour is now avoided, the line being carried directly across the ravine. In some cases the embankments or 'breast walls,' as they are locally called, instead of being constructed of dry stone masonry throughout, are formed of a pair of retaining walls filled in between with soil. The side batter is usually about 1 in 6. The culverts are of dry masonry, faced in mortar, and with the exception of one iron girder bridge, which crosses a turnpike road, the under bridges are all of stone masonry.

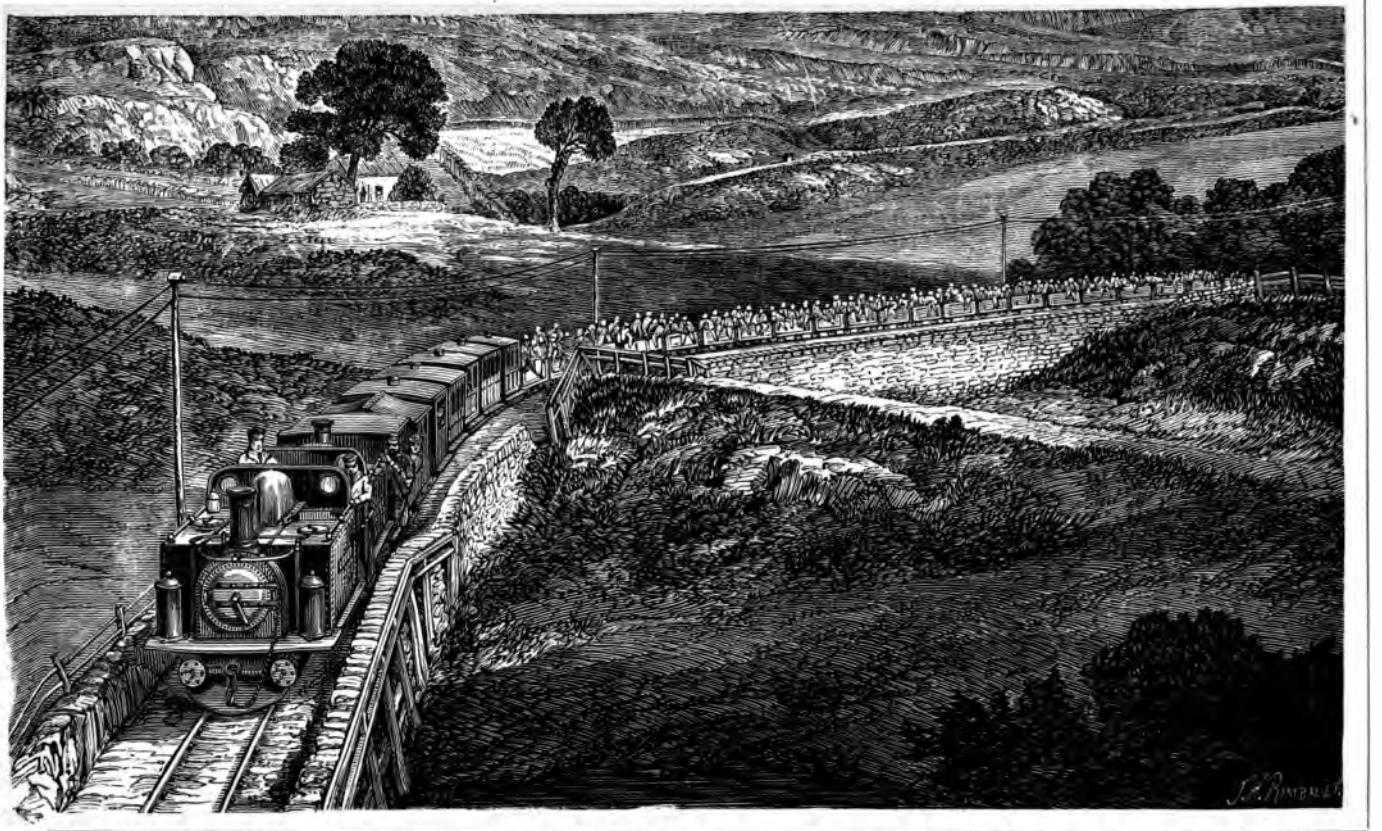
"We have already referred briefly to the permanent way, and we must now enter into further details. In 1832, when the construction of the Festiniog Railway was commenced, it was intended that the line should merely be a tramway, on which the trains of loaded slate wagons should descend by gravity, while the empty trucks, or trucks loaded with coals or sundries, were hauled back by horses. This state of affairs continued until 1863, when, on the recommendation of Mr. C. E. Spooner, the engineer of the line, locomotive power was adopted. During the autumn of 1864 passengers were carried by the company experimentally, without charge, and in the following year the line was regularly opened for passenger traffic. These changes have, of course, necessitated a corresponding change in the permanent way. The rails originally used weighed but 16 lb. per yard, and these were subsequently replaced by others weighing 30 lb. per yard, most of which were laid more than 18 years ago. These 30 lb. rails have, however, in their turn been found too light, and the line is now relaid for the greater part of its length with double-headed rails weighing 48·66 lb. per yard. These rails are fixed by strong chairs to 9 in. by 4½ in. larch cross sleepers, 4 ft. 6 in. long, and placed 3 ft. apart from centre to centre, except at the joints, where the pitch is contracted to 2 ft. At each joint a frame is formed by

placing two sleepers as longitudinals under the cross sleepers, and spiking the latter to them. This arrangement, combined with the use of a very stiff form of fish-plate made to embrace the bottom flange of the rails, enables the joints to be rendered very firm and even, an important matter in a narrow gauge line worked at what are relatively very high speeds. Of the care taken in laying out the curves we have already spoken, and we need merely add, therefore, that in bending the rails accurate work is secured by employing the extremely handy little portable rail-bending machine designed by Mr. Spooner, and illustrated and described by us on page 263 of our eighth volume. A matter to which Mr. Spooner has paid especial attention—and a most important matter it is—is the drainage of the line, and as a result he has obtained one of the best, if not, indeed, *the* very best, pieces of permanent way which we ever inspected. In the course of last autumn we had the opportunity of examining carefully long lengths in different parts of the Festiniog Railway, and we were especially struck by the entire absence of even the slightest sign of subsidence in the ballast, or the least crack indicating a movement in the sleepers. In fact, we may say at once that we never saw a piece of line of any length with the ballast in an equally perfect condition.

"We have directed particular attention to the state of the permanent way on the Festiniog Railway because it is important that it should be borne in mind in considering the capabilities of narrow gauge lines. In writing of this subject more than twelve months ago (*vide* page 385 of our tenth volume) we said: 'The narrower the gauge the greater is the angle through which a vehicle is canted laterally through a certain elevation or depression of one of the rails, and the greater, therefore, is the inequality produced in the loads on the springs on opposite sides, and consequently on the two rails also. In fact, the narrower the gauge the greater the amount of lateral oscillation to which any given inequality in the line

will give rise, and this is a point of special importance in districts where, from the variations of climate or other influences, the permanent way is liable at times to get more or less out of repair.' A consideration of the matters to which we thus directed attention will show the vast importance of maintaining a narrow gauge line in good condition, if it is to be employed for carrying anything like fast traffic. Under the charge of an engineer of energy and capability like Mr. Spooner, having not only the will but the power to maintain his line in practically perfect order, a road of very narrow gauge may, without even incurring risk, be employed to accommodate traffic which it would be simply reckless to run upon a line of the same gauge less thoroughly well constructed and less efficiently maintained. We, therefore, by no means desire it to be inferred that because the Festiniog Railway has for some time very successfully accommodated a relatively fast passenger traffic, and because passenger trains drawn by the Fairlie engine 'Little Wonder' have frequently traversed portions of it at speeds of over 30 miles per hour, that, therefore, similar feats could be safely performed on all lines of 1 ft. 11½ in. gauge. On the Festiniog line, thanks to the perfect condition of its permanent way, the trains run, even at the speed last mentioned, as steadily as on the best piece of 4 ft. 8½ in. gauge line we ever rode upon, and with an entire absence of any shock or jar on entering and leaving curves; but in narrow gauge lines worked under less favourable circumstances an equally satisfactory result can scarcely be expected, and it is therefore desirable that on almost all such lines the gauge adopted, if fast trains are to be run, should materially exceed that of the Festiniog Railway, if only to allow for less perfect maintenance.

"There are besides the termini four intermediate stations on the Festiniog Railway, namely, Minfford Junction (the next station to Portmadoc, where there is the transshipment station, recently referred to by us in our review of Mr. Spooner's book,



DESCENDING TRAIN WITH PASSENGERS, QUARRYMEN, AND WORKMEN, DRAWN BY THE FAIRLIE ENGINE, "LITTLE WONDER."

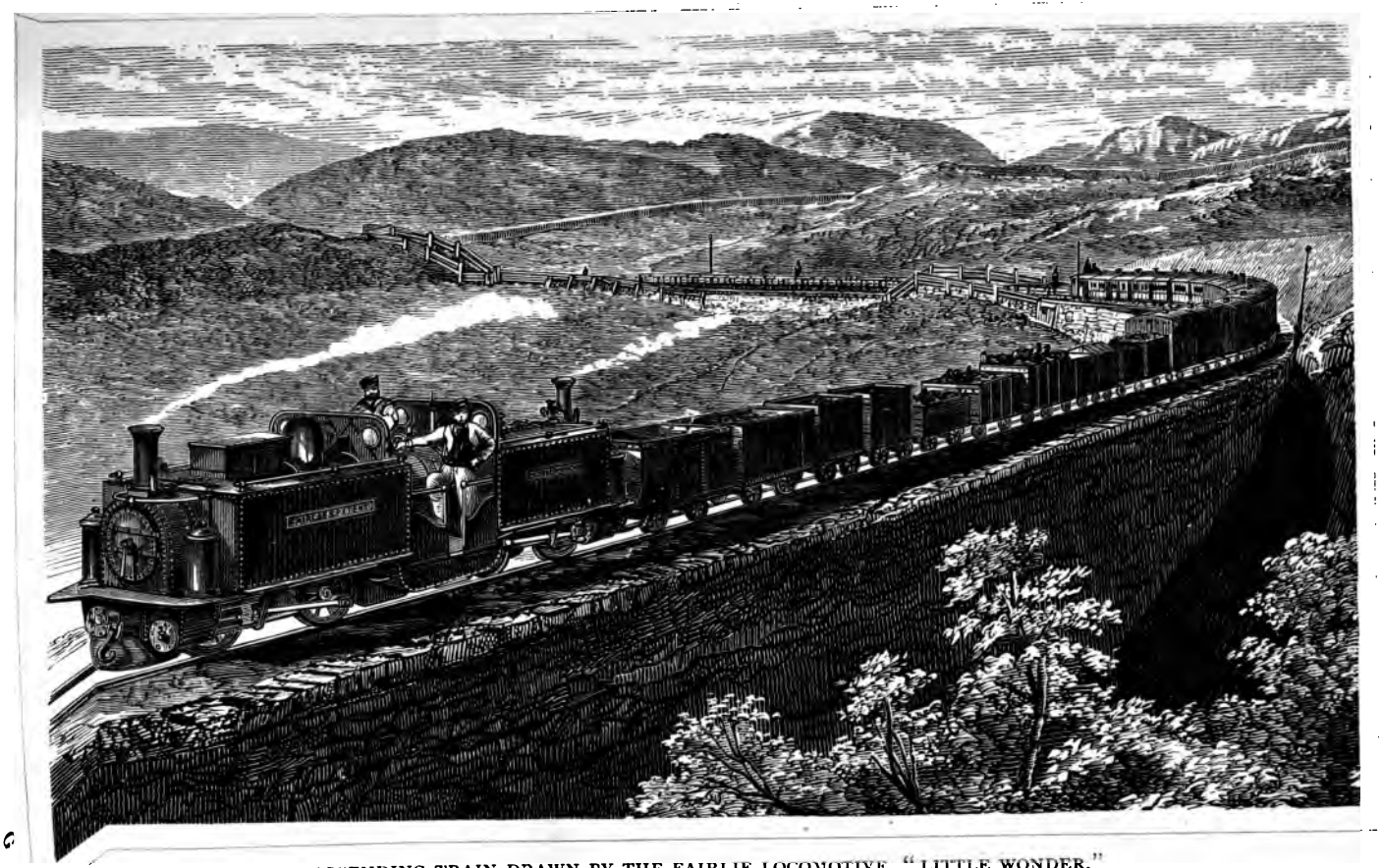
for interchange of traffic with the Cambrian Railway), Penrhyn, Hafod-Llyn, and Tan-y-Grisiau. These stations have no platforms (the lowness of the carriages rendering this unnecessary), but they are provided with all necessary accommodation, although on a small scale. The engine sheds and the principal constructing and repairing shops are about a mile from Portmadoc, although there is also a carriage shed close to the latter station. Everything at these workshops and running sheds is of course in miniature; but it is none the less complete. It is, we believe, only by actually seeing and examining such workshops and sheds as these that the economy attendant upon the maintenance of narrow gauge stock can be thoroughly understood. A railway engineer visiting such shops cannot but be struck by the facilities for repairs which such miniature rolling stock affords. The small parts to be dealt with, the comparatively trifling weights to be lifted, and consequently the simple lifting tackle required, the small wheel lathes and other tools necessary, and many other matters of a similar kind, all have to be seen and examined into personally before they are appreciated at their full value.

"The line is worked on the 'staff' system, assisted by telegraph. All the stations and signal boxes are in telegraphic communication with each other, and the signalling arrangements, &c., are as complete as on ordinary lines of the 4 ft. 8½ in. gauge. The same remark also applies to the systems of points and crossings, turntable, and other fixed plant required for accommodating the traffic.

"We have now to speak of the rolling stock, and we shall commence with the engines. The two locomotives originally built for the line by Messrs. G. England and Co. in 1863, are four-wheeled engines, the wheels being 2 ft. in diameter and coupled. The wheel base is 5 ft. and the cylinders, which are outside, are 8 in. in diameter with 12 in. stroke. The weight of these engines in working order is 8 tons. Subsequently Messrs.

England built five other engines of a similar class, two of them, however, being heavier, and weighing 10 tons in working order. One of the 10-ton engines will take up in ordinary work a train consisting of itself and tender, one first-class, one second-class, and one third-class carriage, a guard's brake-van, four goods wagons, and twenty-four slate wagons, these last being empty. The total gross weight of such a train, inclusive of engine and tender, will be 55 tons, of which about 16 tons consist of passengers and goods carried. During the down journey, the goods wagons being then empty and the slate wagons loaded, the total weight of the train will be about 93 tons, of which 54 tons is paying load carried.

"The year 1869 was marked by the introduction of the Fairlie engine on the Festiniog Railway, and the results which have since been obtained show that Mr. Spooner exercised sound judgment in recommending the adoption of this system. The Fairlie engine, 'Little Wonder,' placed on the line in 1869, was built by Mr. Fairlie at the Hatcham Works, and an illustration and a full description of it appeared in our columns early last year (*vide* page 316 of our ninth volume). We may, however, repeat here that the engine is mounted on two steam bogies, each bogie having four coupled wheels 2 ft. 4 in. in diameter. The wheel base of each bogie is 5 ft., and the total wheel base of the engine 19 ft., while the weight in working order is 19½ tons. Each bogie has a pair of cylinders $8\frac{3}{16}$ in. in diameter, with 13 in. stroke. In ordinary work this engine will take up a train consisting of three carriages (first, second, and third class), a guard's brake-van, six goods wagons, and one hundred and twelve empty slate wagons, the total gross weight, inclusive of engine, being 127½ tons, of which about 21 tons will be passengers and goods carried. On the down journey, when the slate trucks are loaded and the goods wagons empty, the total weight of engine and train is about 336½ tons, of which 230 tons are paying load. During the visit of the Russian Imperial



ASCENDING TRAIN DRAWN BY THE FAIRLIE LOCOMOTIVE, "LITTLE WONDER."

Commission to the Festiniog Railway in February, 1870, the 'Little Wonder' took still greater loads, but as full accounts of these performances were published in our pages at the time, we need merely refer to them here.

"Such a train as that we have just mentioned, as forming an ordinary load for the 'Little Wonder,' measures over 1,200 ft. in length, and on some parts of the line it is thus on three or more curves at once, the different parts of the train being moving towards almost all points of the compass. Riding in one of the last wagons of such a train it is at times difficult for a stranger to realise that the engine which he sees moving along the opposite side of a ravine in a direction almost exactly opposite to that in which he is travelling, can possibly have any connexion with the vehicle in which he is carried. The engravings on pages 418 and 419 (95 and 99), prepared from photographs, will give some—although we fear but a faint—idea of the appearance of these long trains. The first of these views shows a descending train, loaded with passengers, quarrymen, and workmen, passing round one of the 1¾ chain curves, only the engine and six carriages, and about four-and-twenty of the wagons being, however, visible. The other view, on page 419 (99), shows an ascending train of goods wagons, passenger carriages, and empty slate wagons, the front part of the train standing on one of the breast walls already referred to, while further back it extends round one of the 1¾ chain curves. Here again but a portion of the train is visible, the hinder part extending through the bridge shown on the left in the background of the illustration. The line, in fact, forms such a succession of curves that it is almost impossible to obtain a point of view from which one of these long trains can be seen clearly throughout its length.

"It is not, however, for its hauling power alone that the Fairlie locomotive, 'Little Wonder,' is distinguished. An equally important matter is the ease and steadiness with which

it traverses the sharpest curves on the line. We have repeatedly directed attention to this point; but we may nevertheless again speak of the matter here. We have ridden on the buffer beam of one of the bogies of the 'Little Wonder' at speeds up to thirty-five miles per hour, and we can testify to the extraordinary steadiness of the running, both on the straight and curved portions of the line. On the footplate—which is supported by the carrier frame connecting the two bogies—the ease of the motion is still more remarkable; and the expression which has been frequently made use of, that the engine 'appears to glide round the curves,' is really the only one giving a fair idea of the movement. As regards the economy of fuel, also, the 'Little Wonder' has given most satisfactory results, Mr. Spooner stating that her consumption in proportion to the work done is quite 25 per cent. below that of the other engine on the line.

"The present article has already become so lengthy that we must make our remarks concerning the rolling stock of the Festiniog Railway as brief as possible. The passenger carriages in use on the line are of various types. Those most recently built may be regarded as ordinary railway carriages in miniature; but in others the seats are placed longitudinally, the passengers sitting in two rows back to back. In some of these latter carriages there are no sides, the passengers being, however, protected by strong leather aprons which reach about half way up the sides of the carriages and are secured to the ends and intermediate pillars by straps. The carriages with longitudinal seats are 10 ft. long by 6 ft. 3 in. wide (outside dimensions), while they weigh 26 cwt., and carry twelve first class or fourteen second or third-class passengers. The carriages most recently built are 9 ft. 9 in. long by 4 ft. 10½ in. wide outside, or 9 ft. 2 in. long by 4 ft. 6 in. wide, inside dimensions; and each is divided into two compartments by a partition reaching about half the height of the carriage. The seats run transversely as usual, each seat accommodating three persons,

so that each carriage carries twelve passengers. The height is somewhat small, being only 4 ft. 9 in. inside at the centre. The wheel base is 5 ft. 6 in., and the diameter of the wheels both for these and the other carriages and wagons is 1 ft. 6 in. The wheels are of cast-iron with wrought-iron tyres, and the carriages are mounted on springs of the ordinary form. The carriages are well lighted by side windows and a lamp is provided in the roof. The weight of these carriages is but 23 cwt. or less than 2 cwt. per passenger carried.

"The goods wagons are of a number of different patterns, some of them being shown in the view on page 419. The slate trucks are platform wagons with open sides of angle iron, and are of two principal classes, the large carrying 3 tons, and the small carrying 2 tons of slates. A large number of them are provided with simple brakes, it being usual to run the trains with a brake on every sixth truck. The weights, &c., of some of the principal varieties of goods stock are given by Mr. Spooner as follows:

Class of Vehicle.	Wheel base.	Weight empty.	Load carried.
	ft. in.	cwt.	tons.
Coal trucks	5 6	19	3
Goods ,, ...	5 6	18	2½
Bogie timber trucks	3 0	per 26 pair	9
Slate wagons (small)	2 11 / 3 1	13	2
,, ,, (large)	5 0	19	3
,, ,, with brakes	5 0	21	3

"The loads above given for the slate wagons are those carried when fully loaded with large-sized slates. From an inspection, a short time ago, of the books of the company recording the gross weight of, and net load carried by, each train, we found that the proportion of paying load to dead weight varied, in the case of the slate trains, from a little more than 2 to 1 to 3 to 1, the general average being over 2½ to 1 — an excellent result.

The slate wagons, we should mention, are not mounted on springs.

" The whole of the rolling stock is provided with central buffers and couplings, an arrangement which, of course, materially facilitates the passage of the curves. The speed was at first limited by the Board of Trade regulations to twelve miles per hour; but more recently these restrictions have, we believe, been entirely removed, and we have, in fact, travelled over long lengths of the line on the 'Little Wonder' at nearly three times that speed without, as we have already stated, experiencing the least unsteadiness. Of course, however, such a speed as this would not be safe with the four-wheeled engines.

" In conclusion, it is desirable that we give some particulars of the traffic which the Festiniog line is accommodating. We have not the figures for the last year by us, but during 1869 the passengers carried amounted to 97,000, and the goods and mineral traffic to 18,600 tons and 118,132 tons respectively. The train mileage was 45,619 miles, and the engine mileage 50,314 miles. The total receipts for the year were £23,676 12s. 10d., while the cost of working repairs and maintenance was £10,518 6s. 3d., and the special expenditure £2,535 11s. 7d., making the total expenditure £13,053 17s. 10d. The line thus yielded during the year a net revenue of £10,622 15s., equal to a dividend at the rate of 29½ per cent. on the original capital of £36,185 10s., or the rate of 12½ per cent. on the present capital of £86,135 10s. The £50,000 forming the difference between the present and original capital has, we should state, been accumulated out of revenue. Notwithstanding the large amount of traffic it has accommodated, it must be borne in mind that the Festiniog Railway is very far from being worked up to its full capacity. There is no night traffic on it and no Sunday trains, and even by using Fairlie engines in place of the six four-wheeled locomotives at present on the line, nearly double the traffic could be carried.

" We have, we think, said sufficient to show that the Festiniog Railway is a line possessing a vast amount of interest for engineers at the present time when narrow gauge railways are steadily and surely making their way. It is, in fact, the most perfect miniature railway in existence, and it is deserving of being most carefully studied in all its details. We notice that amongst the schemes before Parliament this session is an extension of the Festiniog line on the same gauge to Bettws-y-Coed, the favourite resort of artists. The energy and engineering skill shown by Mr. C. E. Spooner in bringing the Festiniog line to its present admirable state form a sufficient guarantee that if this undertaking receives Parliamentary sanction, as it undoubtedly should do, it will be carried out in a thoroughly satisfactory manner; and from what we know of the district we feel certain that the line is one which would not only be advantageous to the local proprietors, but would also be highly appreciated by the thousands of tourists who annually flock to the beautiful district which it is proposed to traverse."

M. Nördling, formerly chief engineer of the Orléans Central Railway, and since 1869 associated with Baron von Weber, the chief engineer of the Austrian Government railways, has recently collected and published important information* respecting narrow gauge railways at present being worked, and this work contains much new and useful statistics which bear directly upon the question under discussion.

He refers to M. A. Thirion's observations on the French laws for branch lines, 1865 (Observations sur le Projet de loi des Chemin de fer Départmentaux). The main *réseaux* of the French railways have been considered as completed, and the law gives facilities for the construction of branch lines, for connecting remote districts with main line stations. The construction of these branches is left to the authorities of the district through which they run, but the State supplies pecuniary assistance.

* Stimmen über Schmalspurige Eisenbahnen.

After referring to the successful construction and working of such lines in Alsace, M. Thirion, who occupies the important position of Director of the Orléans Central Railway, proceeds to consider whether it will be always possible to construct, under these conditions, a network of branch lines sufficient to meet the requirements of the country. The branch lines in Alsace cost, without preliminary and land expenses, about £4,800 a mile, and the working expenses amount to some £384 per mile, and such an outlay necessitates a traffic equal to at least £640 a mile. But there exist few outlying districts able to command so large a traffic. The experience of the Orléans Central Railway has shown that the traffic in departmental lines seldom exceeds £380 per mile. What then remains to be done under such conditions? Have the branch lines to be abandoned, and have innumerable districts to be left without railways? The only remedy consists in the construction of narrow gauge railways, less expensive than lines of the ordinary type, and requiring a much lighter rolling stock, which may run around curves of 200 ft. radius. The chief objection to narrow gauge for branch lines is, however, the inconvenience of the break of gauge at the point of connexion with the main lines, and the question to be decided is, whether the inconvenience and expense of transferring all goods from one line to the other are not greater than the saving effected in the construction of the narrow gauge.

The Orléans Railway has had exceptional opportunities to obtain information on this point. The coal mines and iron works of Auben are the property of the railway company, and the transport of the coal and ore to the next station, Salle-la-Source, a distance of 4½ miles, was always connected with so many difficulties and inconveniences that the construction of a branch line was decided upon. At first it was proposed to build the line of the ordinary gauge, but a more careful investigation resulted in the adoption of a narrow gauge, with rails weighing from 32 to 38 lb. per yard. The traffic during the

first three years was carried on with horses, but afterwards locomotives were used. This line, called the Mondalazai Railway, is, as just stated, 4½ miles long, with curves varying from 130 to 328 ft. radius: the gauge is 3 ft. 6 in., and the sleepers are laid 2 ft. 5 in. apart. The rolling stock consists of 2 four-wheeled coupled engines, weighing 9 tons, and 70 wagons, each carrying 3·8 tons.

The cost of constructing the line, including permanent ways, stations, &c. &c., was	£2,160 per mile.
The rolling stock cost	1,070 „ „
Total	£3,230 „ „

The rolling stock was built to carry 80,000 tons per annum, but on account of a diminution in business, the traffic amounted only to 50,000 tons. Notwithstanding this considerable reduction, however, the cost of transport per mile was reduced from 3·2d. to 1·2d. per mile during the period of horse-working, and again almost to half the latter amount when steam was employed. The cost of the transport of the ores from the narrow gauge wagon to the station-yard, and thence to the trucks of the broad gauge at Salle-la-Source, was 1·7d. per ton.

The working expenses amounted during one year to £4,260, and this would scarcely have been increased if 80,000 instead of 50,000 tons had been carried. If the Mondalazai Railway were now an independent line, a charge of 1·25d. per mile would be sufficient to pay the working expenses and 5 per cent. on the capital.

These are the facts obtained from the experiments made by the Orléans Company, and though the results are not quite complete, because the Mondalazai line does not carry passengers or any other freight than coal and ore, it is possible to deduce the probable result to be obtained on a similar line employed for general traffic. This has been done by the chief engineer, M. Bertara, who takes as an example a line 15 miles long, with

an average traffic of 120 passengers per day, and 40,000 tons per annum, which gives with a tariff of 1·1d. per passenger, and 1·6d. per ton of goods, a return of £448 per mile. With 12 trains per day, M. Bertara calculates the rolling stock to consist of 6 locomotives, 25 passenger carriages, 40 covered and 60 uncovered wagons, representing altogether a capital of £20,400. Adding to this about £1,200 a mile for construction, we get a total capital of £2,500 a mile; with a speed not exceeding 20 miles an hour, and without any night traffic, the working expenses are calculated at £295 per mile, giving a profit of about £150 a mile, equal to a payment of 6 per cent. on the capital.

After M. Thirion's paper, M. von Nördling reproduces the well-known report of M. Eugène Flachât, in which the author gives an account of the narrow gauge lines constructed up to 1867, beginning with the Festiniog Railway, and passing from the Broelthal Valley line, in Rhenish Prussia, and the one from Antwerp to Ghent, to the well-known Norwegian system.

In the "Mémoires et Comptes-rendus des Travaux de la Société des Ingénieurs Civils," M. Nördling advocated the adoption of the narrow gauge in a series of papers published by him when he held the appointment of chief engineer on the Orléans Central Railway. At first he proposed to work such lines for general traffic on the tramway system, running at low speed, and taking up or setting down passengers at any point. Afterwards he communicated the project for a line of the 3 ft. 3⅜ in. gauge between the town of Saint Pourzain and the Varennes-en-Alliers Station. The distance is about 6 miles, and was estimated to cost £16,800, including rolling stock.

After giving a detailed description of this intended line and an estimate of the traffic, M. Nördling points out that it would be advisable to separate the railway system into two classes: first, the existing lines with the broad gauge, and second, the branch lines with 1 metre gauge, costing about £3,000 per mile. Such an arrangement would involve, of course, a break

of gauge where the lines interchange; if, therefore, the cost of transfer is less than the interest of the saving effected in the cheaper construction, the latter offers decidedly great advantages over the former. The following formula is applicable :—

$$0{\cdot}05\, l\, e > p\,(1 - t)\,T$$

in which $0{\cdot}05$ = interest on capital.

l = the length of the narrow gauge line.

e = the economy in construction expenses per unit of length.

p = the cost of transferring a unit of goods.

t = that portion of the goods which would have to be transferred if the gauge were kept uniform (experience shows this to be $\frac{1}{4}$ or $\frac{1}{5}$).

T = the amount of transferred goods during the year.

If now e = £800; p = 2d. per ton; $t = \frac{1}{4}$; and T = 20,000 tons; the construction of narrow gauge is economically justified *whenever its length exceeds* 3 *miles*. The working expenses are rejected in this formula, or rather they have been assumed to be the same in each case, an incorrect assumption greatly in favour of the broad gauge.

In the Journal of the Association of German Engineers appears a review of a pamphlet published at Liége last year, on light traffic railways, by a commission of State engineers, whose final opinion is, that in consideration of a cheaper construction of their lines, a narrower gauge ought to be adopted than is now recognised.

It is of the greatest importance on all railways to construct them at the smallest possible expense, and by all means in a manner that the capital invested should pay at least 6 per cent. interest. In order to construct and work railways always in a cheap manner, a narrow gauge and special engines should be employed. Narrow gauge ought to be adopted for all branch,

mineral, or other industrial lines; such lines exist in Norway, Denmark, England, France, and Germany. The commission latèly appointed by the administration of German railways proposes gauges of 2 ft. 5½ in. and 3 ft. 3 in., and only if a branch line connected stations, of one and the same railway system, should ordinary wide gauge be adopted.

For narrow gauge lines gradients of ·025 per cent. and curves 200 ft. radius are sanctioned, the weight of the rail and the height of the ballast are to be reduced; the weight of the engines is not to exceed 20 tons, and the speed should be limited to 20 miles an hour, while the rolling stock should run on loose wheels.

The narrow gauge Broelthal Valley Railway pays a dividend of 5·75 per cent. with a daily traffic of 40 tons per mile, and with the ordinary freight tariffs. The Festiniog line, constructed under considerable difficulties, and at great expense, yields a net profit of 12½ per cent.,* whilst the English railways of ordinary gauge scarcely give 4 per cent.

To these two lines may be added as an example the railway from Tavaux to Ponsericourt, in France. The cost and statistics of this line are given in the following Table:

Name of Railway.	Length.	Width of		Ruling gradient.	Ruling curve.	Weight of rail.	Engine.	Cost per mile of construction.	Cost per mile of rolling stock.	Yearly traffic.	Receipt.	Expenses.	Profits.
		Gauge.	Formation.										
Tavaux to Ponsericourt.	miles. 8·75	ft. in. 3 3⅜	ft. in. 6 10½	percent. ·075	feet. 100	lb. 28	tons. 7·5 four wheels.	£ 1,000	£ 1,920	tons. 12,000 in four months.	£ ...	£ ...	...
Festiniog Railway.	14½	1 11½	8 0	·011	115	45	19·00 Fairlie.	5,760	7,290	142,000	23,676	13,053	12½ per ct.
Broelthal Valley.	14	2 9½	5 7½	·0115	125	22	12·5 six-wheeled coupled	13,800	1,700	32,709	2,800	1,232	£ 1,468

* The rate for merchandise on this line is 2·7 pence per ton per mile; and the rate for slates is 1·67 pence per ton per mile.

Many ways may be adopted for effecting a convenient connexion between the narrow and broad gauge, and an important advantage the former possesses is, in the favourable circumstances that carriages and goods for street traffic may be used at once for street traffic by simply changing the wheels, which run loose on the axles. Loaded wagons may then be taken direct to their destination.

Conspicuous in M. Nördling's pamphlet is the Report of Mr. Daniel P. Sullivan to the Austrian Ministry of Public Works upon my system, both as regards gauge and rolling stock, and although nothing has been put forward in this Report that I have not myself urged, the whole question is argued with completeness, and he proves incontestably the advantages that are inseparable from my system, and recommends it to the Austrian Government for adoption on all the new State lines. The Report concludes by an expression of the opinion that while all new lines should be worked by my system, all the existing ones should be gradually reduced in gauge, and changed in management.

Experience has shown that the cost of constructing narrow gauge railways may be reduced by one-fourth or one-third of that of broad gauge, that the cost of the rolling stock may be considerably smaller, and that the working expenses can be reduced to one-half or two-thirds of those on the ordinary lines. The loss of time occasioned by the reduced speed of the trains can be of little importance on branch lines. The expenses connected with transfer of goods from one train to another are generally unestimated; and with proper appliances these expenses may be reduced under the most favourable conditions to 0·4d. per ton, whilst in no case should they exceed 2d. per ton.

Supplemental to this Report of Mr. Sullivan, I cannot do better than reproduce extracts from M. Nördling's Report upon this system, as the opinions of so eminent an authority cannot fail to carry great weight.

"*M. von Nördling on the Fairlie System for the Austrian Railways.*

"Mr. Sullivan's Report deals with two questions of very different natures: first, the advantage of narrow gauge railways; second, the adoption of the Fairlie engines. For many years I have been a steady advocate of narrow gauge, being convinced that it is the only solution of the problem for cheap railway construction and working; and though I do not carry my views so far as Mr. Fairlie does, I am convinced that no country in Europe would derive greater advantage from narrow gauge than Austria, and it is to me remarkable that any opposition should be encountered on the subject, especially as Austria has for several years possessed one of the most interesting lines of this class—the Lambah-Genunden Railway, 3 ft. 6 in. gauge. Public opinion seems to declare itself against the railway, not on account of its reduced width, but by reason probably of its old-fashioned rolling stock and slow speeds.

"Several new lines on the 4 ft. 8½ in. gauge have been sanctioned, which in consequence of the difficult nature of the country will be enormously expensive to construct, and which will be very costly to work. No profitable financial results can be hoped for from these lines if the normal gauge is adhered to, whilst on the other hand, if narrow gauge with all its advantages of building and working were adopted, greater accommodation would be obtained, and the lines could be made to pay.

"*The Adoption of the Fairlie System.*—With respect to the second question contained in Mr. Sullivan's Report, with regard to the application of the Fairlie system, I am inclined to believe all that has been said in his favour, and consider that better results can be obtained with it, than with the rolling stock at present used on narrow gauge lines.

"For all these reasons I would consider it an event of the

utmost importance in railway engineering, and as a great advantage for Austria, if Mr. Fairlie would undertake the construction and working of a narrow gauge railway in that country. I hope that he will undertake it without any Government guarantee, but with a total exemption from all import duties.

"I go, however, so far, on account of the great importance of the results of such a trial, and on account of the full proofs he has to offer, upon the superiority of his system, that I should recommend that Government aid be extended to him. If such an arrangement could be made before long, perhaps the contractors of the Salz-Kammergut line would alter their plan, and a new field would be opened for narrow gauge in Austria, and a similar example would have been set by her, as that she gave before with the railway over the Semmering."

I may now turn to some interesting and valuable statistics connected with narrow gauge railways now in existence, compiled by the well-known Italian engineer, Signor Biglia. These statistics serve to show clearly that actual experience helps out the arguments I have advanced upon the subject.

Referring to the railway of 1·1 metre gauge (3 ft. 7 in.) between Antwerp and Ghent, Signor Biglia says that the receipts in 1868 amounted to 875,222 francs, or 19,500 francs per kilometre (·62 mile); but the working expenses increased from 1866 to 1868 almost exactly as much as the receipts, so that the profits remained about the same—namely, 369,754 francs, a sum sufficient, however, to pay more than 7 per cent. to the shareholders. The directors of the line continue to pursue the prudent course of never burdening the railway with fresh capital, reducing dividend, to accumulate reserve funds for improvements of works. The surplus reserve fund amounted originally to 4,700,000 francs, but it is now 5,200,000 francs. It is upon this capital that the interest of 7 per cent., mentioned above, is paid; but if this was reckoned upon first capital the interest would amount to about 8 per cent.

Signor Biglia quotes these figures to bring under consideration the much discussed question of the cost of transfer of goods with reference to break of gauge.

Observations based upon experience obtained at the Exchange Station of Lockeren, where the narrow gauge, Antwerp and Ghent line, joins the State railways of the ordinary gauge, were recently published by M. Regnard in a paper contributed to the *Société des Ingénieurs Civils*. In the Station of Lockeren the transfer of goods between the two lines amounts to about 15,000 tons per annum. The shifting from one set of wagons to the other by manual labour is in the most primitive manner, except for large blocks of stone or heavy machinery. In shifting these a powerful crane is used in the following manner:—The narrow gauge cars are brought alongside the larger ones, or they follow them on a mixed gauge, and both are brought within range of the crane or shears; coal and loose mineral freight is shifted with shovels. The cost of transfer under such conditions of course reaches a maximum, with the following result:—The total working expense of the transfer station amounts to 6,688 francs per annum, from which must be deducted 2,007 francs for the passenger service, leaving 4,678 francs for the cost of shifting the 15,000 tons of freight, making the cost 3·11d.

M. Regnard describes also a private narrow gauge line in Belgium 1 ft. 11¾ in. wide, on which goods are transferred for 1·5d. per ton, reaching 1·8d. as a maximum; and this price, he asserts, gives a truer average than the experience gained at the Lockeren station of the Antwerp and Ghent line.

I now approach the conclusion of my remarks, in answer to Mr. Seymour's review. I might have extended them to double their present limits, even had I confined myself to replying to those points Mr. Seymour's pamphlet includes, while there are others to which he has not alluded, and which, therefore, I refrain from introducing into these pages. At the same time, I have endeavoured, as far as possible, to keep

strictly within the limits of fact, to advance nothing I am unable to prove, and to maintain nothing which has not been confirmed by experience, and which is not in harmony with common sense. And, indeed, although on many points I have extended my remarks to a greater length than I have hitherto done, there is nothing in this pamphlet the substance of which, at least, has not been long ago put forward by me. At first, indeed, practice was not available to test the correctness of my assertions, but gradually experience has shown that all that I have claimed for properly worked narrow gauge railways may justly be assigned to them; the prejudice which I had to encounter at first I see diminish day by day on every hand, and if I have still to encounter powerful opposition, that opposition is due either to indifference or to prejudice, the indifference arising from a lack of inquiry, and the prejudice springing from conservatism or from interested motives.

I do not wish it to be understood for a moment that I advance myself as the originator of narrow gauge railways; such were in existence, and steam worked, long before the days of the Liverpool and Manchester Railway, and the 3 ft. 6 in. gauge had been reduced into a national system before I addressed myself to the subject. But I do claim to be the first who has asserted that narrow gauge properly worked is equal in its efficiency to the broadest gauge that can be built, and I have shown this assertion to be true. I claim to have pointed out how narrow gauge can be made efficient, and to have perfected the machinery by which alone it can be effected, and I claim so to have spread the truth of narrow gauge doctrine, and so tried to guide public opinion, that to-day thousands of miles of narrow gauge railways are being built or contemplated, and a fair proportion of this mileage is being or will be worked with the Fairlie engines and rolling stock.

There are very few, even among the most bigoted adherents to broad gauge, who will attempt to deny that traffic is carried

with an enormous disproportion of dead weight; in other words, that the vehicles best adapted for the 4 ft. 8½ in. gauge are too large for the paying loads which they are limited to carry by trade requirements. Mr. Seymour clearly admits this in recommending that narrow gauge cars should be placed on broad gauge framing. Is it not strange, then, that it should be so difficult to convince engineers that it would be more economical to build railways in closer proportion to their business requirements, to reduce the size and weight of wagons until an economical ratio between dead and paying load is reached, to achieve with this all the advantages which a lighter, more handy stock confers, to be enabled to build a cheaper road, and to reduce the expenses of working, and the cost of repairs? The requirement is so urgent, and the solution of the problem so clear, that it cannot be inability to understand it.

But there are many who admit that narrow gauge has certain advantages, that for a light and uncertain traffic cheap small lines are well suited. The engineers who take this ground have not sufficiently studied the question. They see broad gauge on a reduced scale, reduced width, reduced capacity, efficiency, speed, and safety, forgetting that, properly worked, no limit can be set to the capacity of a narrow gauge line, and that high speeds can be obtained upon it with safety. For a new and poor country, say they, narrow gauge is appropriate, and so far they are right, for in poor countries cheapness in first cost is all important. But I maintain that for all countries, poor or rich, for all classes of line, trunk or branch, in narrow gauge, and narrow gauge alone, can all the advantages of a railway system culminate. I except of course those special circumstances where a speed of from 45 to 60 miles an hour is required; in such cases economy is but of secondary importance, and although I believe that any practicable speed is safe upon a 3 ft. 6 in. gauge, I would, until I have a wider experience, hesitate to recommend a higher rate than 45 miles an hour for such a gauge.

FAIRLIE STOCK.

FOR THE

DUNEDIN & PORT CHALMERS RAILWAY, NEW ZEALAND.

3 ft. 6 in. Gauge.

COMPOSITE CARRIAGE.

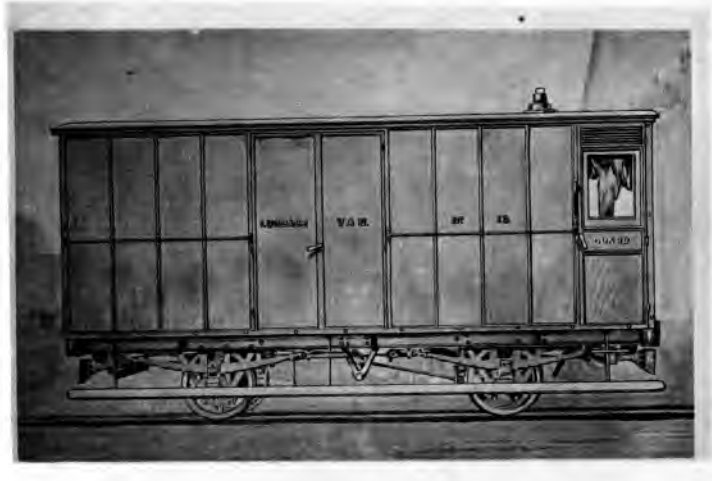
Weight, 3 tons 12 cwt.

To Carry—Short Journeys { 8 First Class, 20 Second Class Long Journeys { 6 First Class, 16 Second Class

---

PASSENGERS' LUGGAGE BRAKE VAN.

With Double Screw Brake. Weight 3 tons 1 cwt.



But upon all ordinary lines of passenger and of goods traffic I most unhesitatingly recommend either a 3 ft. or a 3 ft. 6 in. gauge, and for the reasons I have previously advanced. Summarised these advantages are :—

First. The narrow gauge, by reason of its diminished width, and of the greater facility it possesses of accommodating itself to the natural surface of the ground, can be constructed for about two-thirds of what a broad gauge line would cost.

Second. The rolling stock can be constructed of dimensions more in proportion to the loads it will have to carry, reducing the amount of dead weight, because the freight, which would be but a very small portion of a full load for a broad gauge car, will approximate nominally to the full load of the smaller narrow gauge car, which can be built lighter per ton of capacity than can the broad gauge vehicle; moreover, the proportions of the former can be with economy adapted to the gauge, which cannot be done with the latter, for while light and narrow gauge cars 7 ft. wide can be built, cars double the width of the broad gauge would be enormously heavy, and would be of no use if they were built.

Third. The saving in hauling empty trucks is reduced in the same proportion, as the cost of conveying full ones is diminished, the ease of handling such small stock is greater, and the repairs of wagons which are not loaded with a great, and not only inert, but destructive dead weight, is far less, for it must be remembered that the dead weight of stock is an active cause of its deterioration.

Fourth. The dead weight being less on the narrow than on the broad gauge, the stress upon the rails is diminished, and the wheel base being shorter, the facility of passing curves is increased, and consequently the wear of the rails is reduced, a wear still further affected by the fact that the slip of the outer rail is less on the narrow than on the broad gauge.

Fifth. The locomotive power required to haul a given paying

load on a narrow gauge line is less than that required to draw the same load on a broad gauge line, from the fact that the dead weight of the vehicles is less in the former case, and in practice, as only partial loads can be obtained per wagon, the advantage in favour of the narrow gauge is very striking.

Sixth. Permitting of a great reduction in the enormous dead weight inseparable from broad gauge, the maintenance and repair of permanent way, engine, and rolling stock are reduced, so that the economy in first outlay continues to be a source of saving in the working of the line.

Upon two of the most important questions, reduction of dead weight and break of gauge, Mr. Seymour and myself are quite in accord; upon the question of comparative safety also we are agreed; even upon relative speed there is not much difference of opinion between us, but he cannot yet relinquish the gauge in which he has been brought up. All else he abandons, and by his recommendation he absolutely admits that General Buell's report ought to be followed. I have, I hope, shown clearly why the suggestion of Mr. Seymour to adopt narrow gauge vehicles to a broad gauge road is an impracticable one, although I freely admit that with ordinary locomotive power the narrow gauge sinks at once into insignificance. And it is upon this point that I claim to have done all; it is by perfecting a mechanical arrangement, that I was the first to propose some years ago, that I have been enabled to make the narrow superior in point of efficiency and economy to the broad gauge. It is the Fairlie engine, which at once changes the small line of railway from being one of very insignificant capacity, and having but a limited measure of usefulness, into a line capable of accommodating any quantity of traffic; for the power of the Fairlie engine not being dependent upon the width of the line upon which it runs, it follows that a far greater amount of freight can be conveyed by an engine on the narrow than on the broad gauge, for not only is the power of the engine greater,

FAIRLIE STOCK,

FOR THE

DUNEDIN & PORT CHALMERS RAILWAY, NEW ZEALAND.

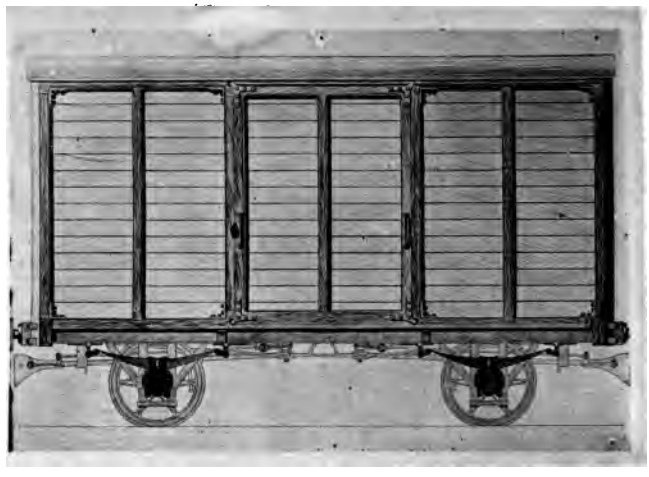
3 ft. 6 in. Gauge.

COVERED GOODS VAN

Weight, 2 tons 15 cwt.; to carry 7 tons; Capacity, 546 cubic feet.

OPEN GOODS WAGON.

Weight, 2 tons 7 cwt.; to carry 7 tons.



weight for weight, as I have explained before, but the dead load to be carried is so much reduced that the paying efficiency of the engine is greatly increased.

The advantages I claim for the Fairlie engine are:

First. That it solves the great problem of narrow gauge, and makes such lines as efficient as lines of the greatest width.

Second. That the whole of the weight of the engine is utilised for adhesion, an advantage impossible upon any other engine, unless combined with a long rigid wheel base.

Third. The Fairlie engine having a very short wheel base can pass around the sharpest curves, without injury to the track or distress to the engine, and at the same time the perfect articulation of the underframes to the boiler allows of free movement vertical and horizontal.

Fourth. That while the whole weight of the engine is utilised for adhesion in mounting heavy gradients, the subdivision of weight reduces the load per wheel upon the rail so greatly that a lighter section of rail may be employed than it would be safe to use with ordinary and consequently far less powerful engines.

Fifth. That while the large heating surface which can be obtained by my system will enable a narrow gauge engine to haul with ease a load up long steep gradients, which it would be impossible for ordinary engines of the same gauge to mount because their steam would give out, the water level over the fire-box always remains constant. Hence the proposition to run two ordinary engines coupled together to do the work of one Fairlie engine is not a practical one, because the two engines with a full load behind them would drop their steam as quickly as one, and because whilst the water level in one engine was very high over the fire-box, the fire-box of the other might be uncovered.

Sixth. That the Fairlie engine develops more power and works more economically, and with a saving of fuel, shown by

experience to be not less than 25 per cent., than any two ordinary engines of the same vital dimensions.

Seventh. That over the roughest roads the Fairlie engine rides with the utmost smoothness. A long experience has fully proved the truth of this. Exactly the same advantages exist, if a comparison between the Fairlie engine and the ordinary locomotive on the standard gauge be made, it being always understood that the amount of traffic is sufficiently large.

Against the use of the Fairlie engine for narrow gauge railways it is urged:

First. That the engine may be more powerful than is required for the traffic, and that two ordinary engines would be more suitably employed, together when necessary, separately under ordinary circumstances.

The first objection is a very strong argument for narrow gauge, for if the ordinary locomotive of very limited power be sufficient for general traffic, how disproportioned would a 4 ft. 8½ in. gauge line be for a traffic which can be managed by an ordinary engine upon a narrow gauge. But I maintain that by proper organisation sufficient heavy trains can always be despatched (unless the line is utterly insignificant), and it is obviously cheaper to run one long train than two short ones drawn by separate machines. The occasional coupling up of the two engines, I have just alluded to.

Second. It is asserted that the steam joints connecting the boiler with the cylinders and exhaust will not keep tight. Experience shows this assertion to be quite without foundation.

Third. The repairs are stated to be excessive. This again is wrong, as proved by experience.

Fourth. It is also alleged that the Fairlie engines would be too powerful for the coupling chains of the ordinary wagon stock, and that for this reason advantage could not be taken of the full measure of their capacity, forgetting that the capacity

FAIRLIE ENGINE,

BUILT FOR THE MEXICAN RAILWAY.

4 ft. 8½ in. Gauge.

4 Cylinders, 15 in. diameter, 22 in. Stroke ; Wheels, 3 ft. 6 in. diameter, all coupled ; Collective Heating Surface, 1687 square feet ; Carries 2,200 gallons Water, 20 cwt. Coal, 180 cubic feet Wood ; Weight in working order, 59 tons ; Tractive Force at Rails (mean pressure 100 lbs) =21,600 lbs.

FAIRLIE ENGINE

BUILT FOR THE

DUNEDIN & PORT CHALMERS RAILWAY, NEW ZEALAND.

3 ft. 6 in. Gauge.

4 Cylinders, 10 in. diameter, 18 in. Stroke ; Wheel, 3 ft. 9 in. diameter, all coupled ; Collective Heating Surface, 892 square feet ; Carries 890 gallons Water, 17 cwt. Coal ; Weight in working order, 28 tons ; Tractive Force at Rails (mean pressure 100 lbs.)=8,000 lbs.

FAIRLIE'S PATENT

JOHNSBURG
FAIRLIE PATENT

of these engines can be made to suit any traffic, however limited; but I state distinctly that one of the principal causes of coupling chains breaking now is *the want of power in the ordinary engine*, because these engines can only start their trains when the wagons are coupled up loose, that is to say with from 6 to 12 inches' space between the buffers of opposite wagons; therefore the engines start wagon after wagon according to the slack of the couplings, and in this manner may have moved 7 or 8 yards before the last wagon in the train is started. It will be readily conceived that this mode of starting a train requires great caution on the part of the driver, because the sudden jerk or pull on the wagons in rear of the train when the forward portion is moving from 3 to 4 miles an hour is most trying to the coupling chains, and frequently causes them to break away. Couplings never break by fair and even pulling; it is the snatch or jerk they receive when starting that does all the damage. This slackness of the couplings also mainly conduces to wagons breaking away, because on an uneven road some of the wagons suddenly overrun the others, and bumping up lift the coupling-link out of the hook which joins the wagons together, and the driver finds his train has parted in the middle; this frequently happens on inclines, and the wagons which become unloosed soon begin a retrograde movement and run down the incline, often causing loss of life and immense destruction of property.

These sudden snatches or jerks are very destructive to the wagons, because the pull being direct on the frame the tendency is to pull the frame away from the body of the wagon containing the load: this may be noticed particularly when cattle are being carried, and how the animals are knocked against the end of the wagon and frequently thrown down and injured; the same occurs when the train is stopping, but this time it is caused by the bumping or the running up of the slack of the couplings, and just reversing the above order of things, but

equally destructive to the wagons and load they carry. I maintain that this bumping and jerking is more destructive and costs more money for maintenance than if the wagons ran ten times the number of miles they now do with loads; it necessitates the wagons being very much heavier than they ever need to be, the couplings stronger, and thus they destroy each other by reason of their own dead weight.

Now, with the Fairlie engine and stock the carriages and wagons are all coupled up tight one with the other, so that there can neither be bumping nor jerking, because the Fairlie engine, by reason of its four cylinders, *can start any train on any gradient that it can take at a rate of* 12 *miles an hour*, consequently the wagons may be reduced in weight, whilst the couplings in use at present will be found amply strong for trains double the length, and the life of the wagons would be largely increased and the expenses of maintenance reduced to a minimum.

Fifth. That on passing over the apex of a reverse incline, the leading wheels of the leading bogie, descending whilst the trailing bogie continues to ascend, are liable to leave the rails, because the normal weight on them is removed by reason of the centre line through the bogie and that through the boiler remaining parallel to each other, and thus lightening the forward end of the engine to a dangerous degree. This reasoning is most decidedly wrong, and as the objection has been raised outside of Mr. Seymour's remarks by a gentleman who is considered one of our best locomotive engineers, I have thought it desirable to answer this latter allegation a little more fully than I could in the body of this paper, and I have therefore shown the fallacy of this reasoning in the Appendix.

The last and greatest objection to the Fairlie engine in this country is that it *is* the Fairlie engine. The same unreasoning prejudice which endeavours to prevent the development of

FAIRLIE ENGINE

BUILT FOR THE PATILLOS RAILWAY, PERU.

2 ft. 6 in. Gauge.

4 Cylinders, 10 in. diameter, 18 in. Stroke; Wheels, 3 ft. 3 in. diameter, all coupled; Collective Heating Surface, 829 square feet; Carries 800 gallons Water, 17 cwt. Coal; Weight in working order, 26 tons; Tractive Force at Rails (mean pressure 100 lbs.) = 9,230 lbs.

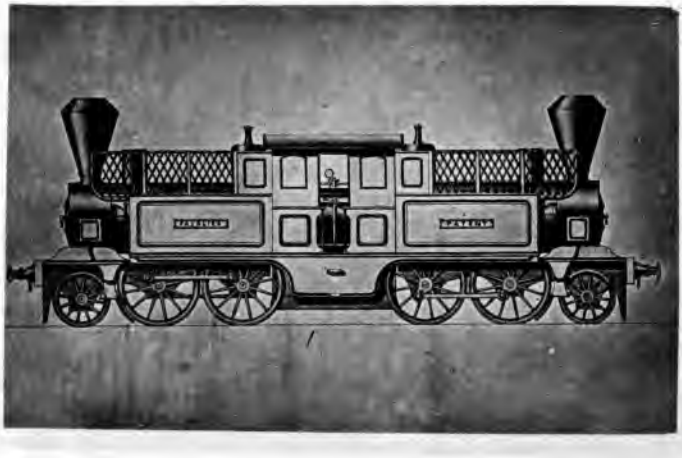
FAIRLIE EXPRESS MAIL ENGINE

FOR THE GRAND RUSSIAN RAILWAY.

5 ft. Gauge.

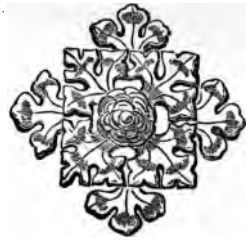
4 Cylinders, 14 in. diameter, 22 in. Stroke; 8 coupled Wheels, 5 ft. 6 in. diameter; Leading Wheels, 3 ft. 6 in. diameter; Collective Heating Surface, 1,520 square feet; Carries 2,400 gallons Water, 360 cubic feet Wood; Weight in working order, 54 tons; Tractive Force at Rails (mean pressure 100 lbs.) = 13,000 lbs.

LAGUNAS



Narrow Gauge Railways extends also, and not perhaps unnaturally, to the means of developing their usefulness.

And now I leave this great and all-important question of narrow gauge railways to the consideration of the public, with the hope that I have fully demonstrated the truth of the statement I made in a paper read by me at Liverpool in 1870, before the members of the British Association — a statement that ought to be engraved on the mind of every engineer, that *every inch added to the width of a gauge beyond what is absolutely necessary for the traffic adds to the cost of construction, increases the proportion of dead weight, increases the cost of working, and, in consequence, increases the tariffs to the public, and by so much reduces the useful effect of the railway.*



THE DENVER AND RIO GRANDE RAILWAY.

SINCE this Pamphlet was written I have received a Report from the well-known pen of Samuel Bowles, Esq., upon the Denver and Rio Grande Railway, reference to which I have already made, and the following extracts from it will show how fully facts bear out the statements I have advanced :—

Two years ago, when there was not a mile of running track in all Colorado, and the silence of its vast plains had never been broken by the screech of the locomotive, Denver was talking of the "Coloradian System of Railways,"—whereof, of course, that town was to be the centre,—with as much scientific confidence and elaborateness of detail as a young surgeon expounds to oppressed ignorance the marvellous and intricate system of the human body. If the listener was inclined to be incredulous, his instincts taught him not to show it, and he heard, and wondered at, and worshipped before Western audacity. But now he comes again, and sees the whole thing illustrated and achieved; so far illustrated, at least, as to make sure of every detail originally proposed, and some that were hardly dreamed of then.

Five distinct railroads now make Denver their centre:—the Kansas Pacific, which forms her direct and main connexion with the East; the Denver Pacific, running nearly a hundred miles north, and making connexion with the Union Pacific trunk line at Cheyenne; the Boulder Valley road, thirty miles north-west, into the foot-hills of the mountains, already opening extensive coal beds to Denver furnaces and grates, and another year destined to add twenty miles more, that will carry its track into the centre of a rich gold and silver country; the Colorado Central, striking due west into the mountains, open now twenty miles to Golden City in the foot-hills, and graded far up the wonderful Clear Creek canyon toward the great mining centre of Central City, forty miles away, which is also to be reached in another year; and last, the Denver and Rio Grande Rail-

way, running due south, and open now to the point where I date my letter, seventy-six miles below Denver. Still progressing southward, the latter line is to be farther opened forty-three miles to the thriving town of Pueblo on the Arkansas river early next spring. Beyond these open and running lines, with their extensions, several other railroad schemes are organising, and promise to be soon in the way of execution. One of these is the cut-off line to the Union Pacific, running north-east from Denver to Julesburg, on that road, 100 miles east of Cheyenne, and passing through a fine farming and grazing country in north-eastern Colorado. This enterprise is under the patronage of the Union Pacific road, as the Denver Pacific is under the control of the Kansas Pacific, and will give to the Union Pacific what it now fails to have, a fair chance of the eastern business of Colorado. Another project is a line from Denver, Canon City, or Colorado Springs, into the South Park country and the centre of its mineral wealth, with an ultimate destination, by the way of the "Hoosier Pass," or the head waters of the Arkansas, in the valley of Salt Lake, and there making connexion with the California Central Pacific line, which would give the latter the advantage of two connexions with the East. Besides these, as the two main and most promising new enterprises, there are several projects for branches of the present lines for the opening up of coal or gold and silver regions of proved value, within the mountain ranges or along under their shadows.

The main purpose of the present letter is to describe this Denver and Rio Grande enterprise, which is the beginning of a great north and south line from the centre of the United States to the centre of Mexico, running along the high plateau, just under the great mountain backbone of the continent, through a country rich in agriculture and mineral resources, and offering great inducements by these, as also by its healthful climate, to an extended immigration. To the nation, if not to Colorado itself, this is the most important element in the boasted railway system of the latter. Then, as a special and immediate occasion for interest, attracting to its construction and operation the attention of all railway builders and managers, this line is built upon the now famous Narrow Gauge principle. There are two short roads of this character in Canada, running through agricultural regions. But this one here may be fairly counted the first that boldly enters the arena of open competition and defiance with the ordinary or broad gauge lines, and, taking a field of undisputed value for railroad construction and general business, chooses the narrow gauge, not only because it is cheaper in construction, but with the faith that it will prove more economical and useful in doing a general business traffic of

unlimited proportions and continental grasp. The successful construction and operation of the first seventy-six miles of such a line, running through an open country as favourable for the construction of a broad line as almost any other section of our Western plains, has fairly startled the whole railway interest of the world, drawn thither in critical examination railway people, not only from all parts of America, but from Europe, and fully inaugurated a new War of the Gauges. The old war, represented by the Erie line with 6 ft., and nearly all other American and European lines with 4 ft. 8½ in., had been fought out and won by the lesser width; but now the latter is itself challenged by this Lilliputian of 3 ft. to prove its right, on grounds of economy and capacity, to continue master of the field. It is not for me, it is not for any man, indeed, thus early, to decide the question. I may only state its points, and describe the progress of the experiment that here, almost in the very wilds of Central America, has so suddenly and sharply raised the issue,—a fact in itself as romantic and unique as any of the many romantic and unique innovations and revolutions America has thrust upon a steady-going world; and finally to confess the deep impression which has been made upon me by what I have seen and heard in connexion with this enterprise.

The road and its trains, in the first place, look like a railway plaything, in contrast with the broader and heavier tracks and larger cars of the accustomed lines; delicate and dainty, they seem almost too faint and feeble for the hard, quick work to which they are called, and especially unequal to the great contest which they have invited. Yet so far, surely, they are performing their task with ease, with comfort, with celerity, and with success. The track-bed of the narrow gauge is 10 to 12 ft. wide, as against 15 ft.; the distance between the rails 3 ft., as against 4 ft. 8½ in.; the ties are 6½ ft., as against 8 ft.; the rails weigh 30 lb. to the yard, as against 56; the engines 12 to 16 tons, as against 25 to 30 tons, putting about half the weight on the drive-wheels that the larger locomotives do; the passenger cars, with 8 wheels, and carrying 32 passengers, weigh 6 tons, as against 18 tons, 8 wheels and 50 passengers; and the freight cars, so far introduced, weigh 2 tons, run on 4 wheels, and carry 4 to 5 tons of freight, as against cars weighing 9 tons on 8 wheels, and capable of 10 tons' load. Where four passengers sit in the ordinary car, three are seated in the narrow ones, two on one side and one on the other of the passage way, the car being divided in the middle by a door, and the seats for two and one, respectively, being reversed in the two sections, so as to balance the carriage. The cars at first introduced are 7 ft. wide, and 10½ ft. high from rail to top. They prove a trifle more compact than is necessary,

and not quite generous enough in accommodations for passengers; but this evil is being remedied in new cars now constructing; while sleeping cars and day drawing-room cars can be made for the narrow gauge roads, which will accommodate still more persons, in proportion to their size and weight, than the ordinary cars of this character now do. The new freight cars are on 8 wheels, weigh 3¼ tons, and carry 9 tons. The box cars for general merchandise weigh 4 tons, and carry from 8 to 9 tons.

The cost of constructing these seventy-six miles, with equipment,—*including stations, snow sheds, fences, complete ballasting, car and machine shops, hotels, offices, and every appurtenance for business,*—has been $14,000 *a mile*, while the Kansas Pacific road, going through a similar country, and built under the same engineers, and very much by the *same contractors, cost* $22,000. The new road, however, had some advantages in cheaper labour, larger experience, and more ready access to ties and certain other materials. The fair difference between the two roads in an open country like this, it seems to me, would be less than these figures; but in entering a mountain region, where heavy excavations and tunnels were required, hills to be climbed, and sharp corners to be turned, it would undoubtedly prove much more. There is grading going on just now, for instance, up the Clear Creek canyon to the mountain mining centre of Colorado, *which it was estimated would cost* $90,000 *a mile for the full width road*, but which *has been done for* $20,000 *for the narrow gauge.* Perhaps, therefore, taking the average of railroad construction, it is not unfair to claim that narrow gauge lines can be built and equipped *for about three-fifths the cost of the ordinary gauge.* Consider, in this connexion, also, the great advantage the cheap and narrow road has over the broad and expensive one, in the greater ease with which it can meet its burthen of interest. This account is the "Old Man of the Sea" that fastens itself on the shoulders of every new railroad company, and many a sad story could be told of the way in which struggling enterprises have been crushed by degrees and ultimately absorbed by the bondholders. But as the narrow gauge costs but three-fifths of the broad gauge, it is burthened with but three-fifths as much interest. At the same time it has *the same capacity* to meet the *larger interest* as the broad gauge, since it carries *at full rates all the freight and passengers* that the broad gauge would receive. In other words, all other things being equal, the safety of money invested in narrow gauge bonds is, to that invested in a similar broad gauge security, *as five is to three.*

Starting from Denver, this road runs up the valleys of the Platte and its tributaries to the top of what is called the "Colorado Divide," which is a

spur or ridge of high land running out from the mountain range at right angles, and separating the waters of the Platte from the Arkansas. It is 8,000 ft. high at the summit, a rise of 2,000 ft. from Denver; but the ascent is quite gradual, and nowhere amounts to over 1 in 70 ft. to the mile for the track of the road. Then the road descends at about the same rate per mile to this point, which is some 6,000 ft. high, and the centre of the Pike Peak contributions to the Arkansas river. The narrow gauge road claims no advantage over the broad in the matter of grades, except that its trains have *less dead weight to carry, and so can surmount a heavy ascent on less expenditure of power;* but in ability to turn corners it has at *least a double advantage.*

Next and most important of all is the question of economy in operation. Where the advantages of the narrow gauge lie in this respect is partially illustrated in some of the foregoing figures of the weights and capacities of engines and cars. The principle underlying them is this: that given sufficient width of track to give capacity of carriage, all further increase of width increases the weight of engines and cars in greater proportion than it increases capacity; in other words, that the dead weight of a train increases with the width of the track. On this doctrine the narrow gauge rests its claim—over this the battle is to be fought. If it is true, if experience sustains what is claimed for it—and so far it would seem to be fairly illustrated in practice—then the narrow gauge wins the fight; otherwise not. The reader will see, by referring to the weights and capacities of the cars, previously given, that the narrow gauge can carry twice as many passengers and more than twice as much freight per ton of car than the ordinary gauge—that is, of two trains weighing one hundred tons each, the narrow gauge train will carry twice the number of passengers, or twice the number of tons of freight, that the ordinary gauge train would. This is a remarkable statement, certainly. Probably some qualification is to be given to it on the assumption—which it seems to me must be admitted—that the narrow gauge cars, as illustrated here, are too light and too small, while the ordinary gauge cars are unnecessarily heavy. Still, making all allowances in either direction for necessity of increasing, for possibility of decreasing, and the rule would appear so far to hold good, that, given full trains, the narrow gauge roads can carry a much greater proportion of live or paying weight than the ordinary gauge road can. In practice, furthermore, the advantage would seem to be still more on the side of the narrow gauge road; for, as a matter of fact, we know that few trains carry their full capacity either of passengers or freight; there is always great waste of room. It is probably very rare that an ordinary freight train has

as many tons of live weight as it has of dead weight; the excess may indeed never be said to be on the side of live weight; while, when we consider how much more freight goes one way than another on most roads, and, therefore, how many empty or half-filled cars have to be drawn one way, also, when we consider the necessities of local traffic, and the number of quarter or half-filled cars required to be sent off for its accommodation, we may readily believe that the average excess of dead weight is very large.

Now it is claimed for the narrow gauge roads that, by virtue of the principle stated, there is absolute certainty of a reduction of this great discrepancy by their use; and furthermore, that in actual experience, where cars must often be half loaded, or go one way wholly empty, *the advantage of their smaller and lighter cars will afford still greater gains in power and material.* This rests very much on theory so far, it is true; there has been no full and fair experience yet with narrow gauge lines doing a general business, and put in direct comparison with the ordinary or broad gauge; but the theory is certainly a very plausible one, and such experience as there has been sustains it; and together, theory and experience have raised up a belief in the superiority of the narrow gauge that is bringing it rapidly and on a large scale into public favour and practical adoption.

The Russian Government has ordered a 3 ft. 6 in. gauge for new and important lines in that country. In India, after a severe contest between the advocates of the old and the new principles, a gauge of 3 ft. 3 in. has been formally adopted for its great system of railways, and the beginning of many thousands of miles of road of that gauge is settled.

It will be perceived by these incidental statements of different widths, that the narrow gauge advocates have apparently not settled upon a definite width. The Festiniog road in Wales, which was the practical beginning of the narrow gauges, is only 2 ft. wide, but its business is almost entirely that of conveying slate, and it is almost universally held to be too narrow for general purposes. The Norwegian roads, which seem to have been the next of the narrow gauges, are of 3 ft. 6 in. in width, but they run through an agricultural and sparsely settled country, and are denied by the principal advocates of the narrow gauge the place of models. The Russians have taken the same width, however, partly through the virtue of their neighbours' example, but more, perhaps, as a compromise with the old engineers, who hold to the broad gauge; while India's selection of 3 ft. 3 in. is because that is the width of the French metre, which stands in scientific circles as the future standard of measurement. Mr. Fairlie, however, the British civil engineer, who has identified himself most prominently with

narrow gauge interests, thinks that 3 ft. is the royal medium. It gives, he argues, sufficient capacity, while it reduces dead weight to the lowest proportion consistent therewith; if the width is made smaller the capacity decreases unduly, if it is made larger the dead weight similarly increases. Under this argument, and the example of the experiment here, 3 ft. is generally adopted as the American narrow gauge standard; and it will surprise those who have not made themselves familiar with railroad movements and discussions during the last six months to know how firmly and widely the narrow gauge idea has taken hold of American railway development.

There is, indeed, an almost narrow gauge contagion in this country, and most of the new lines projected in the West have either adopted this principle or are seriously considering the propriety of doing so. *The Colorado Central Railroad into the mountains from Denver is changing to the narrow gauge, and its proposed extension east to a connexion with the Union Pacific at Pine Bluff will be of the same width. The road* in course of construction *from Ogden through northern Utah* pointed toward Montana, and known as the *Northern Utah road, is narrow gauge*, and the iron is already ordered for some of its first sections. A new line across the plains from the Missouri river to Denver, starting from Leavenworth, and known as the *Leavenworth and Denver road* (600 *miles long*), is not only projected on the narrow gauge, but has been graded for something *like a hundred miles*, the iron bought, and the equipment is in course of construction. Leavenworth's great railroad king, "Len" Smith, who has the credit of having bought Mr. Caldwell's place in the United States Senate for him, is the father of this enterprise, while the ubiquitous and absorbing "Tom" Scott, of the Pennsylvania Central Railroad ring, gives it his endorsement and encouragement. *The great Southern Pacific road beginning in Texas* has voted to adopt the narrow gauge, but its action in this respect requires the confirmation of the Government at Washington. *A narrow gauge road* between *Terre Haute* and *Cincinnati* has been commenced; *a narrow gauge branch of the Pennsylvania Central into the semi-bituminous coal regions is in progress;* the *Arkansas Central, from Helena to Little Rock*, with a branch to the Sulphur Springs, is laying a *track on the narrow gauge*, and has ordered its cars; *while almost every State, from Massachusetts to California*, is represented by embryo schemes, either of trunk lines or local branches, upon the new principle. St. Louis is agitating herself with a magnificent plan of a new air line *narrow gauge road direct to New York, with branches to the interior of New England and to Philadelphia and Washington.* She has drawn it all out on paper,

figured up the cost, and divided the expense among the counties of the several States through which it is destined to pass. Another great narrow gauge project is that of some of the Pennsylvania coal land owners *for a straight line from their coal mines into the heart of New England*, for the purpose of laying down in your manufacturing regions the raw material for steam at the lowest possible cost. And as for Colorado, she has narrow gauge "on the brain;" Denver's new street *railroad is of the narrow gauge;* a narrow gauge nomenclature and illustration possesses society, and enriches or debases, as you please, the local language. Not the worst by any means of these latter innovations is the new name given for a "jackass," to wit, a "narrow gauge mule."

Of course the possession of so many railroads of the broad gauge is felt to be a great practical obstacle to the new idea. The impossibility of making connexions—that is, of transferring cars from one gauge to the other, will greatly determine many projects, and practically prevent a too rapid growth of the new railroads before their superiority is absolutely proven. But the cost of transferring freight from one car to another is popularly exaggerated. With mechanical appliances the expense of this business may be reduced to an almost infinitesimal proportion of the freight charges; and there is no sufficient reason, on this ground at least, against the introduction of the narrow gauge for branch roads of existing lines, running into a mountainous country or through a sparsely settled agricultural region, with not means enough to build the wider and more expensive roads, but stinted in their development and suffering in their loneliness for the want of some railroad connexion with the business and social worlds. At any rate, the narrow gauge boldly throws down the gauntlet, and challenges the old lines to equal combat, making no apologies for itself, accepting no limitations, but insisting that, as well in the open country as among the hills, as well for a great business as for a small, for all reasons and not solely for a few, it has every advantage, and only awaits time and opportunity to prove it.

Something more is due, also, to the management of this great initial narrow gauge enterprise in America. The active leaders in it are Philadelphians and Coloradians; the capital comes from Philadelphia in part, but chiefly from England and Holland. Gen. William J. Palmer, who is a graduate of the war, of the Pennsylvania Central Railroad, and of the Kansas Pacific Railroad, is the practical engineer and president; and J. Edgar Thomson, S. M. Felton, and Robert H. Lamborn, of Philadelphia, and ex-Governor A. C. Hunt, of Colorado, are his efficient coadjutors. The road is bonded for $16,000 a mile, and the money has been

obtained for its completion to Pueblo, 119 miles below Denver, while negotiations are going on for the means to push it rapidly on, into and through New Mexico, and indeed clear up to the Halls of the Montezumas themselves. Eighty-six miles beyond Pueblo is Trinidad, the last important town in Colorado; to the Rio Grande river is about 100 miles more; then to Sante Fé 75 miles; then to Albuquerque, on the 35th parallel, is 100 miles, and here the road will cross the line of the Atlantic and Pacific road going west to California; to El Paso, on the Mexican border, and the line of the Texas Pacific railroad, is 260 miles farther still from Albuquerque; to Chihuahua is 350 miles more; and finally from that city to the capital of Mexico is 650 miles. Thus the total distance from Denver to the Mexican line is about 750 miles, and from there to the capital of Mexico 1,000 miles.

It seems now probable that this distance will be accomplished and these places reached by this road, before they will be by any other from the United States; that New Mexico, with its important trade, its various and rich agricultural and mineral resources, will be first opened up by way of Colorado; and that the probable annexation of Mexico to the United States will receive its first and great practical impulse by the emigration that will flow along this high table-land in the centre of the continent—a vast region of temperate climate, of the productions of the temperate zone, of health and wealth, and every way of large capacities for population and prosperity. These are important suggestions for the political student and the statesman. They lift this road into more national importance than it has even as the initial and representative of the narrow gauge railroads of America. For the same reasons that the railroad striking south from Missouri and Kansas, through the Indian territory, into Texas, will be the signal and the source of a new prosperity for that great region, this similar line, going through a like fertile and richly endowed region to Mexico, free from the malaria, free from the tropical temptations and depressing and debasing influences of the coast country, will similarly inaugurate a new era for Mexico, give her new populations, new material growth, and a new political future.

Mexico, it should be remembered, has a population of 9,000,000, is without a navigable river, and yet has only 200 miles of railroad. On the other hand, that part of the United States lying west of the Mississippi river, including St. Louis, has less than half that number of inhabitants, but has the Missouri, Arkansas, Columbia and Sacramento rivers open to steamboats and rafts, and still has to-day fully 4,000 miles of railroads. Consider these contrasts; consider that at the city of Mexico, Vera Cruz

is 200 miles distant to the east, and the Pacific Ocean is 600 miles distant to the west; consider also the great wealth of that country in minerals, most especially in silver; and we see a field and a capacity for development and improvement, of which this little hundred miles of narrow gauge railroad in Colorado is the beginning of the key, and by whose rapid extension Americans are destined first and speedily to unlock and enter upon it all. No civilised country offers a series of more important towns, open to modern enterprise, to string upon a line of railroad. Thus, there are Queretaro, Guanajuate, San Louis Potosi, Zacatecus, Durango, and Chihuahua, with populations running from twenty to eighty thousand each, and nearly everyone ready to ship its silver by the ton.

Connected, furthermore, with these suggestions, is the fact that General Rosecrans and a few associates have recently obtained from the Government of Mexico an important railroad grant for lines across its country from Vera Cruz through the city of Mexico to the Pacific Ocean, a grant rich in lands and in freedom from taxation. To make this grant available in full degree, the plan of this north and south line into the heart of Mexico is almost absolutely necessary; and America and Mexico may well join hands in giving it favour, and through favour rapid progress.

A REPLY

TO

MR. RAMSBOTTOM'S REPORT AGAINST THE PRINCIPLE OF THE FAIRLIE ENGINE.

In 1867, three engines *professedly* embodying my principle were built in this country by order of the Crown agents of the Colonies, and were sent to Queensland to work upon the narrow gauge (3 ft. 6 in.) railways in that colony. Only one of these engines was put together and tried in Australia, and then although the other two were never unpacked from their cases, all three were condemned as useless. After some years' delay, they were re-shipped to this country, and in October last two separate reports were made upon them, one of these reports having been prepared by the eminent locomotive engineer, Mr. J. Ramsbottom. Now, as these engines *were not constructed in any measure upon my designs*, and as I never saw them until after their re-consignment to this country, I have nothing to urge against the strictures Mr. Ramsbottom passes upon certain of their details. But as his report contains condemnations of the *principle* of the Fairlie engine, I find this a convenient opportunity of replying to his allegations, as they enable me clearly to point out some of the leading advantages of my locomotive as compared with the ordinary type of engine.

In his report, Mr. Ramsbottom alleges, in condemning the principle, that a serious defect in the Fairlie engine is to be found in the bogie frames, which, although they are free to move in a *horizontal* plane, are not free to move in relation to the boiler

in a *vertical* plane,* all vertical action being prevented by the mode of attaching or coupling the bogies together. With the view of testing this part of the arrangement, Mr. Ramsbottom decided to have a portion of a temporary road raised to a point as shown in Fig. 1, which had been previously laid to a minimum curve, round which to test these engines; and he asserts that the result, on passing the engines over the summit of the gradient, was to reduce the weight upon the leading pair of wheels so materially as to show that the engine was unsafe for travelling over such a description of road, and on this ground he has founded his chief objection to the principle.

Mr. Marshall, the other reporter upon these Queensland engines, repeats in more forcible language the above objections, and illustrates his remarks with the diagram (Fig. 1).

Now, with all due deference to Mr. Ramsbottom's very extensive knowledge of the ordinary type of locomotives in general, this sweeping condemnation, which is echoed by Mr. Marshall, shows that he certainly has a very limited knowledge of the "Fairlie" engine in particular, as I shall now proceed to prove.

Assuming, for argument's sake, the two bogies of the engines in question to be held perfectly rigid vertically, like a girder—a thing utterly impossible—yet, under such conditions, the alleged effect when the engine was standing on the crown or apex of a reverse gradient of 1 in 100 could not be produced. In order to better illustrate my argument, I have introduced some diagrams of the Queensland engine as it is, and of the ordinary type of goods engine usually employed.

Fig. 2 represents the Queensland engine placed on a reverse incline in the position referred to, excepting that, to give more effect, I have chosen an incline 1 in 50 instead of 1 in 100, with the object of exaggerating the case against myself, because

* As a matter of fact, the bogie frames of Fairlie engines proper are free to move both horizontally and vertically.

if there is danger in the one case it is just double in the other; but it will be seen that the weight on the leading pair of wheels in the leading bogie is never so materially reduced as to render the engines unsafe for travelling on the reverse incline of 1 in 50, let alone on 1 in 100; nor is any portion of their weight carried or supported on the stay across the horns of the bogie frame under the axle-boxes. There is, in fact, a clearance of ¼ in., as I shall show further on; consequently, there is not only the weight of the wheels, axles, and boxes on the rails; but there is, in addition, the downward pressure of the springs acting on the ¼ in. clearance between the bottom of the axle-box and the cross-stay of the horns of the frame.

Assuming, as I have said, that the two bogies are so rigid in their vertical length as to represent a girder, their horizontal line will then remain parallel to the centre line of the boiler. In Fig. 2, I have placed the two bogies and boiler parallel to each other, as this represents the very worst possible position for my case—a position which, I assert, is an impossible one, but I have done so in order to show more clearly the fallacy of Mr. Ramsbottom's argument.

The principle of supporting the boiler over the middle axles may be better understood from an examination of Fig. 3, which represents a balk of timber supported at each end on a point over the centre axle, this point being, of course, carried equally by all the axles. The Fairlie boiler is supported in a similar manner; it rests on the bogie centres over the middle wheels.

The boilers of the Queensland engines are supported over the centre wheels A A Fig. 2, of each bogie, therefore, when the engine would be in the position represented, the centre line of the boiler B B would be parallel to a line drawn through the centres of the axles of the wheels A A. If we assume the centre line of each bogie, C C, to be fixed rigidly parallel to the centre line of boiler B B, it will also be found to be parallel to the line A A; then, by drawing the line D D through the

Fig.1.

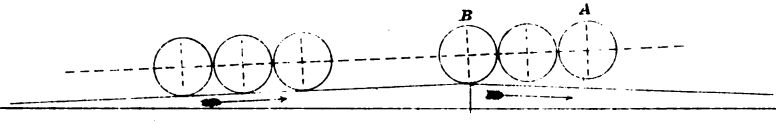


Fig.2.

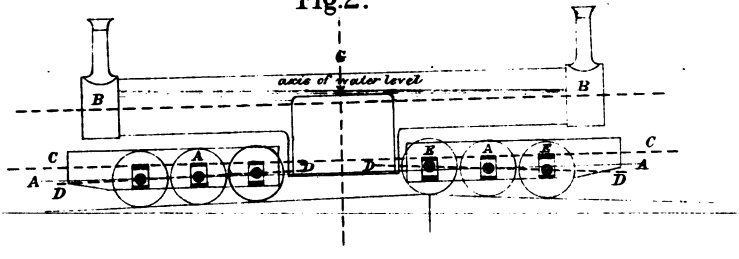


Fig.3.

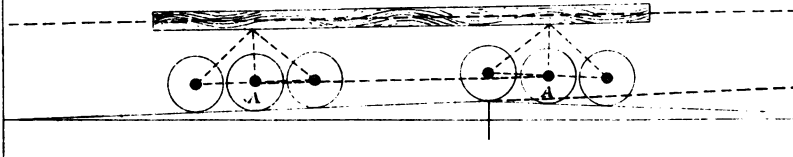


Fig.4.

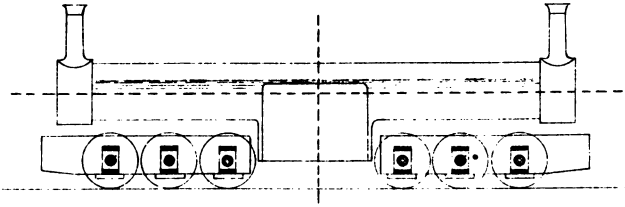


Fig.5.

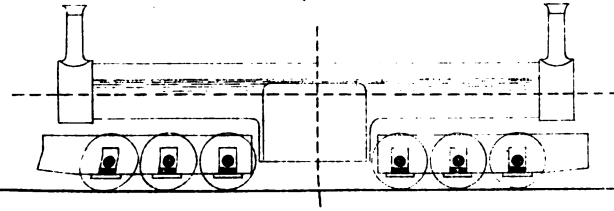


Fig. 6.

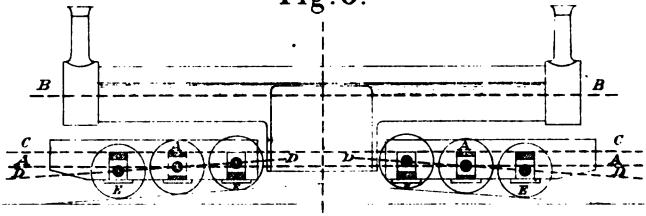


Fig. 7.

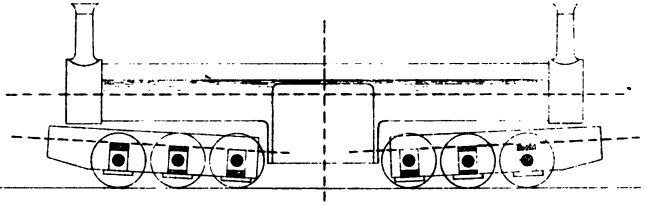


Fig. 8.

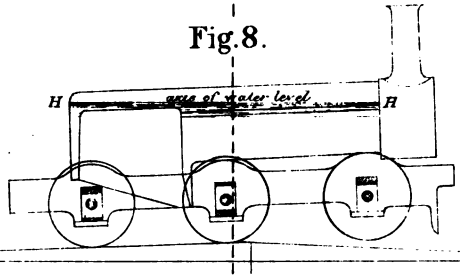


Fig. 9.

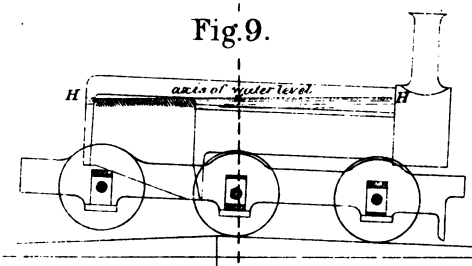
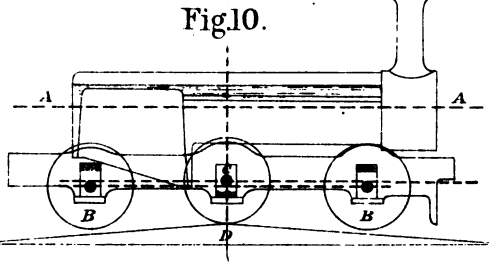


Fig. 10.



centres of the axles of the wheels E E, which, of course, are parallel to the rails, we shall find that the line D D is not parallel with the lines A A, B B, and C C to the extent of the inclination of the rails on half the length of the wheel base E E; that is to say, the wheel base of each bogie of these engines being 6 ft. 3 in., and the inclination of the line 1 in 50, it follows that the greatest distance the centres of the axles of the wheels E E, represented by the line D D, would be out of parallelism with the lines A A, B B, and C C, would be ¾ of an inch above and ¾ of an inch below the centre line A A. Now, if we bear in mind (though the centres of the axles of the wheels E E can never alter their distance from the rails so long as the wheels have a bearing on them) that there is provision made in those parts of the frames of all locomotives wherein the wheels are placed and retained in position, which permits any end of the bogie frame over the centres of the wheels E E to be raised above, or lowered below the centres of the axles to the extent of 1 inch, which means that any frame may be lowered, keeping its centre line and that of the axles perfectly parallel, until it rests on the top of the axle boxes, see Fig. 5, the distance the frame falls being about 1 inch, or, on the other hand, as there is an equal clearance of 1 inch below as well as above the axle boxes, it will be readily understood that one end of the frame may be lowered 1 inch and the other end raised 1 inch, see Fig. 7; whereas in Fig. 6 another form is shown, keeping the frame and boiler lines parallel, but raising and lowering the end wheels to the full extent of 2 inches, indicating the rate of incline. The following Figs. 4, 5, and 7 further illustrate this part of the question.

Fig. 4 shows the frames and wheels as they would be, say, on a level line, with the proper clearances above and below the axle boxes. Fig. 5 shows the frame lowered to rest on the axle boxes, and Fig. 7 shows the frame raised at one end and lowered at the other to the full extent of the usual 1 inch clearance.

I am particular in explaining this section of the locomotive, as only by a full comprehension of it can the reader be enabled to determine the true relative positions of the double bogie and the ordinary engine on the reverse incline indicated in Mr. Ramsbottom's report.

Returning now to the argument before us with this knowledge of the clearances between engine-frames and axle boxes of wheels, we shall find that the centre line of the bogie C C, Fig. 2, though maintaining throughout its parallelism with the centre line of boiler B B, will permit the centre line of the axles D D to alter their parallelism to the extent of 1 inch above and 1 inch below the line A A (see Fig. 6), consequently as only ¾ of an inch is required to maintain the position of the wheels on the rails on the reverse incline of 1 in 50, it follows that there is not only the entire weight of the leading wheels, axles, and boxes on the rails in the position of the engine selected by Mr. Ramsbottom as indicating what he calls a serious defect in the double bogie, but that of the force arising from the action of the springs above them acting through the ¼ inch clearance to spare between the bottom of the leading axle boxes and the guards of the frame at one end, and the top of the trailing axle boxes and top of the frame at the other; these clearances are distinctly shown in Fig. 2.

I now approach that part of Mr. Ramsbottom's argument which testifies to the truth of the old adage that "those who live in glass houses should not throw stones." Having proved that Mr. Ramsbottom's principal objection to the Fairlie Engine has no foundation in fact, it is but fair that I should be permitted to criticise under the same circumstances that Mr. Ramsbottom has applied to my engine, the engine which he so strongly recommends.

Fig. 8 shows the position of his Goods Engine going up and over the apex of an incline of 1 in 50 under the same conditions as those offered for my engine. It is evident that when

the centre wheel of his engine is within say 5ft. of the apex of the incline (the same clearances being allowed above and below the axle boxes in each case), the leading wheels will have dropped as low as the frames will permit—that is to say, 1 in.; in other words, the leading end of the frame will have followed the upward inclination of the line whilst the wheels will have followed, after passing the apex, the downward inclination of the rails as far as the clearances below the axle boxes will have let them, and the engine still moving forward, the entire weight of the leading wheels will be carried by the guards placed across the horns of the frames, and as the centre wheels approach nearer to the apex of the line, the leading wheels will be suspended in the air over the rails, their elevation increasing until the engine has moved forward so far that the weight of its leading end counter-balances the trailing end, and the machine topples over, lifting the trailing wheels and suspending them in air (see Fig. 9), and these only reach the rails again as the engine passes down the incline; or in other words, the centre lines of the frame and boiler, always remaining parallel to each other,* continue to pass up the incline parallel to the rails, whilst the leading wheels, after passing the apex, descend the incline until the axle boxes rest on the cross stay of the horn plates. When this takes place, the frame still ascending, one of two things must happen: either that the wheels are heavy enough to pull over the frame, or, as what actually would happen, the frame would lift the wheels and carry them on until the centre wheels of the engine, getting near to or on the apex, would gradually absorb the entire weight of the whole machine on themselves, and thus form a centre, like a beam scales, until the weight of the leading wheels gradually counter-balanced the trailing wheels,

* The centre lines of boiler and frames of Mr. Ramsbottom's engine must remain parallel with the rails up and down, whilst this is not the case with the Fairlie. See fig. 3.

and the mass toppled over on the leading wheels. It must not be forgotten that for a considerable portion of the time this most dangerous proceeding is going on, the centre wheels are bearing not only their own load but the entire load of each end of the engine alternately, and that actually for a very short distance before and after the centre wheels reach the top, and whilst on it, the *entire weight of the engine is borne on the centre wheels* alone; the best illustration I can give of this motion being to liken the engine frame and boiler as acting the part of a see-saw during the time it is toppling over from the one pair of wheels to the other, whereas this movement cannot possibly take place *under any combination of circumstances with the Fairlie double bogie engine*, though the load would vary a little on the wheels E E of the bogie to the difference only between the forces of the two springs, one being compressed the other expanded, both beyond their normal condition, whilst the *load on the centre wheels remains the same always.*

The whole matter is so plain and easily understood that it, fortunately for me, does not require any engineering skill to comprehend it. The diagrams of Mr. Ramsbottom's engine, as well as the Queensland engine, are drawn correctly to scale, but the rate of inclination of the rail is exaggerated a little to better illustrate their positions on the inclines. In further proof of these positions I give the following dimensions :—

The wheel base of his goods engine (the same argument and conditions apply to all *ordinary engines*, whether for goods or passenger trains) is 15′ 6″, and therefore on an incline of 1 in 50, half up and half down, the centre line of his boiler, A A, and the centres of the wheels B B, would each be 2″ below a line drawn through the centre of the middle axle C, parallel with the centre line AA of boiler. This position is shown by Fig. 10, excepting that as the wheels B B cannot drop 2″, there being only 1″ clearance, the diagram is shown with the wheels

down as far as they can go, the full inch, and the remaining inch is shown in space between these wheels and the rails; in other words, this engine, standing with the middle pair of wheels resting on the apex D of a reverse incline of 1 in 50, and the weight equal at each side of the centre, the entire weight of the engine would be carried on the centre wheels C, and the end wheels, B B, would be standing clear of the rails one inch. Having now, I trust, clearly shown the utter fallacy of this portion of Mr. Ramsbottom's argument, a portion on which he evidently lays great stress, I avail myself of the several diagrams to show another feature of the question of the "Fairlie" versus Ramsbottom's engines, which, though of the gravest importance, seems to have been entirely lost sight of by that gentleman. This feature is the water level in the boilers on inclines. It will be seen in the "Fairlie" engine, Fig. 2, that the centre of the fire-box G is the axis of the water *at all times and positions* of the engine—that is to say, there being 4″ of water over the fire-box of a "Fairlie" double boiler on the level, the same quantity *exactly* will be maintained over *the centre* of the fire-box of the same boiler *on any incline.* The fire-boxes of Fairlie double boiler engines being in the centre it follows that the water will remain always at the same level over the centre of the box, precisely similar to a spirit level.

Let us now see how Mr. Ramsbottom's boiler would be affected under the same circumstances.

The fire-box of his engine is placed at one end of the boiler, and the consequence of this is that so long as the engine is going up an incline with the fire-box towards its lowest end, there will always be plenty of water over it (see H H, Fig. 8), but the instant the position of the engine is changed to H H, Fig. 9, the water leaves the fire-box end uncovered, and risk is incurred of its being burned; it is well known that a burned fire-box is one of the most serious items of expense in the locomotive engine. Moreover, when going up the incline, the

water being very high over the fire-box end, where the water gauge is placed by which the driver ascertains the position of the water in his boiler, this gauge is filled far beyond its highest indicating point, therefore the driver has to feed his boiler entirely by guesswork, and has to constantly bear in mind during his upward journey that though his glass is far beyond being full, the instant his engine commences the descent the water as instantaneously leaves his fire-box and his glass without a drop in it; therefore, on steep inclines, a great deal must depend with Mr. Ramsbottom's engines on the intelligence of the driver, whereas the water gauge being in the centre or axis of the water in the Fairlie boilers it must always, whether on level or incline, indicate the true position of the water.*

---

* This water difficulty increases with every inch added to the length of the ordinary description of boiler. Take for example the case of the Meyer engine. The boilers of those engines must be from 3 to 5 ft. longer than Mr. Ramsbottom's boiler, consequently it will be found very unsuitable, if not altogether impossible, to employ or use them on any lines having but very moderate gradients indeed.

☞ Such a thing as an apex being permitted to occur on any line is unknown to my experience: what I mean by an apex is that rails are never so laid on a grade up and down as to form a distinct angle, but its introduction in Messrs. Ramsbottom and Marshall's reports only shows how far the opponents to the principle of the double bogie engine will permit themselves to be carried in order to find some excuse to damage it, forgetting the old and very trite adage of cutting sticks to break our own heads.

DIAGRAMS OF PAYING LOADS AND DEAD WEIGHTS.

In the following diagrams an endeavour has been made to compare graphically the paying loads and dead weights upon lines of different gauges, as well for the passenger as the goods traffic. For this purpose I have selected seven gauges of different character, namely—the 3 ft. and the 3 ft. 6 in., worked with the Fairlie stock, the 3 ft. 6 in. Norwegian, the 4 ft. 8½ in. French, and the same in this country, the 5 ft. 6 in. and the 4 ft. 8½ in. American gauges. It has been impossible, of course, to do more than show approximate effects, but as the same conditions are applied to each gauge the comparison is a fair one.

The diagrams have been compiled upon the basis afforded by the passenger and goods traffic on the French main lines, the statistics of which are so complete as to leave little to be desired. At the same time it must be remembered that by taking this practice as a standard, a far less favourable result is obtained for the narrow gauge than if I had assumed the more extravagant system of working in this country and in America. I have preferred, however, to adopt French practice as my basis, because it approaches more nearly than that of any other system to economical broad gauge working. I may merely add that the speeds are assumed to be the same upon each gauge, the 3 ft. being suitable for any of the working average speeds developed on the larger gauges. The weight of engines is in no case included in the comparison.

In Diagram I. are shown the seating capacities and cubic space, the dead weight and the paying loads of passenger rolling stock upon the different gauges above mentioned. The signification of the various lines is so clearly explained in the diagram that I may, I think, dismiss it with a very short description. To avoid complication, the three classes of passenger stock have been taken together, and the average only laid down upon the diagram. The net dead weight per carriage shown in the fourth line of the diagram is as close an approximation to actual practice as could be reached where so many differing types exist.

The weights given, however, for the two first narrow gauge carriages are those which I obtain in my own practice. The number of seats offered

per carriage, as laid down on the diagram, are the average of the three classes—the American stock, which has practically but one class, only excepted. For the broader gauges 24, 40, and 50 passengers for the first, second, and third classes respectively are assumed, giving an average of seating capacity per vehicle of 38, as shown. On the narrow gauges an average of 26 passengers per carriage is obtained. The line corresponding with the "number of seats offered per carriage" is that marked "number of seats occupied per carriage." This number has been taken at 25 per cent. in each case. This line of "seats occupied" may be compared with that of "net dead weight" close beside it, and it will be seen that going upwards from the 15 ton American car, where 14 seats are occupied, the lines gradually diverge towards the top of the diagram, until at the 3ft. gauge they show 6·5 seats occupied, with a net dead load of 3·25 tons, that is to say that in the latter case half the useful capacity is obtained with one-fourth the dead weight. This result is shown in the line marked "Dead weight in tons to carry one ton of passengers, as actually employed in practice." From this line it will be seen that the dead load decreases from 16 tons of car per ton of passengers on the American lines to about 10·5 tons on the French railways, diminishing to 8·5 and 7·75 tons on the 3 ft. 6 in. and 3 ft. gauge respectively. On the other hand, the American stock shows the highest result upon the line marked "Number of cubic feet offered per passenger." This is on account of the greater height and less economical seating arrangements which rule in the American stock, and that this apparent advantage is gained only by a great excess of dead weight is proved by the line marked "Number of cubic feet per ton of carriage." In this it will be seen that while the American cars give about 180 cubic feet per ton, the 3 ft. and 3 ft. 6 in. gauge carriages of the Fairlie type give over 215 cubic feet per ton.* And 180 cubic feet per ton is more than is obtained with the American stock in general practice.

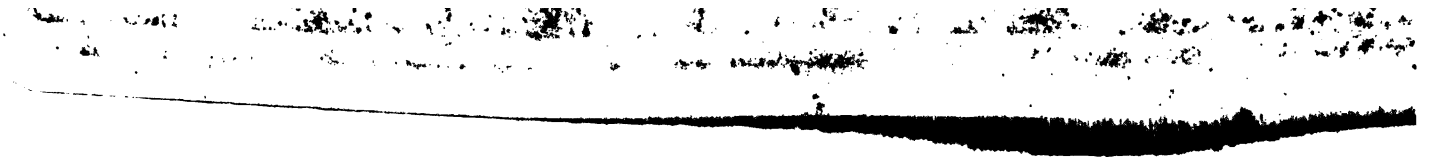
In Diagram II. the proportions of paying to non-paying loads of an average goods train are shown upon the same gauges as are included in the previous diagram.

The number of passengers is assumed to be 60, their weight 4 tons, and the percentage of seats occupied to seats offered to be 25, as in the preceding diagram. The same percentage is also taken for the empty mileage, so that in estimating the total dead weight of train the proportion of empty

---

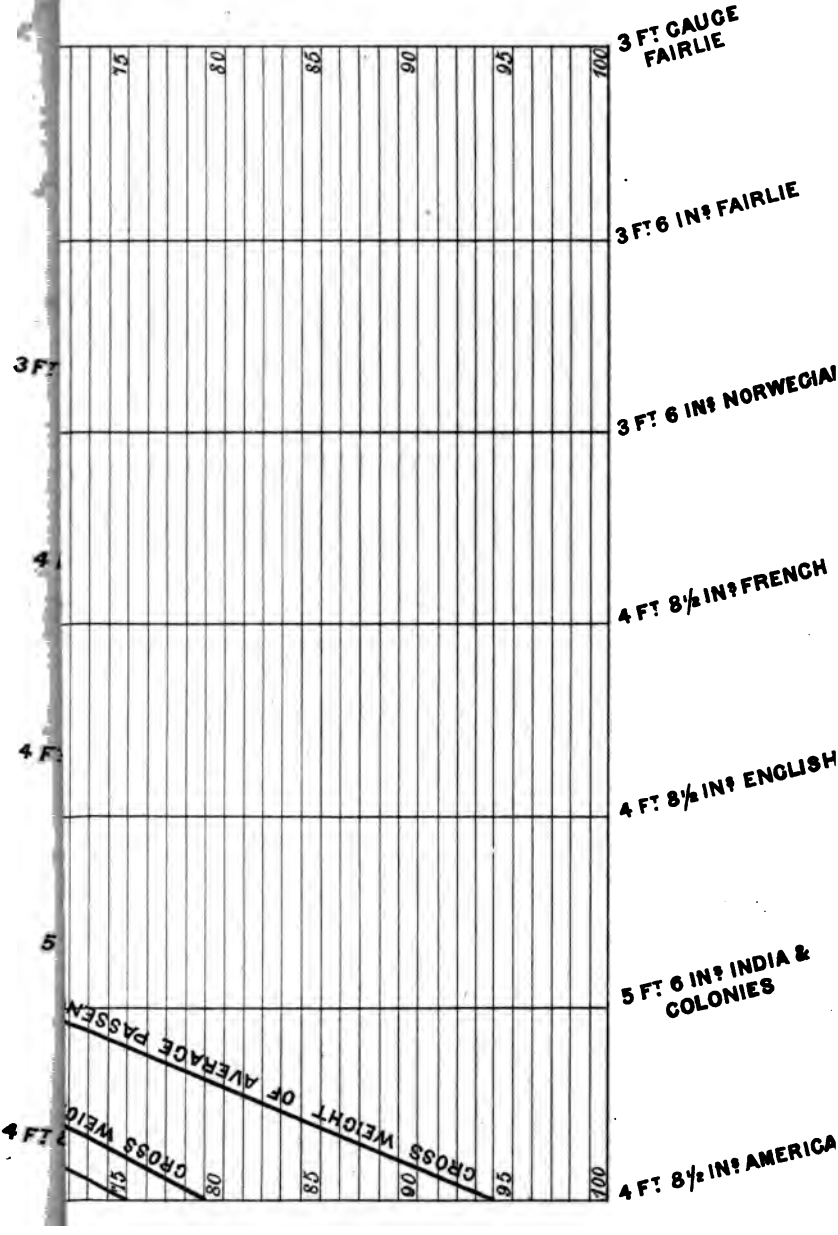
* The scale for cubic feet on the diagram is only one-fifth that of the other scales, so that each space between the vertical lines on the diagram represents 5 cubic feet.

L
T
P
C
C
3 FT
FAIR
3 FT 6 IN? F
3 FT 6 IN? NOR
4 FT 8½ IN? F
4 FT 8½ IN? E
5 FT 6 IN?
COLONIES
4 FT 8½ IN? AM



N°2.

TO NON-PAYING
FFERENT GAUGES
OMOTIVE.



mileage has to be added, as shown by a separate line. The lines show respectively the weight of passengers carried, the number of carriage tons required to carry one ton of passengers, and the net and gross weights of the average train, in all cases exclusive of the weight of the engine, which of course would decrease as the total weight to be moved is diminished. In this diagram the details shown in Diagram I. for one carriage are, in fact, extended to the average train.

The annexed table gives the number and weight of carriages upon the different gauges that would be required to carry any number of passengers from 1 to 100 in first or second class carriages, if the vehicles are filled to their maximum capacity. If only filled to the average degree, the dead weight would be fourfold in each case.

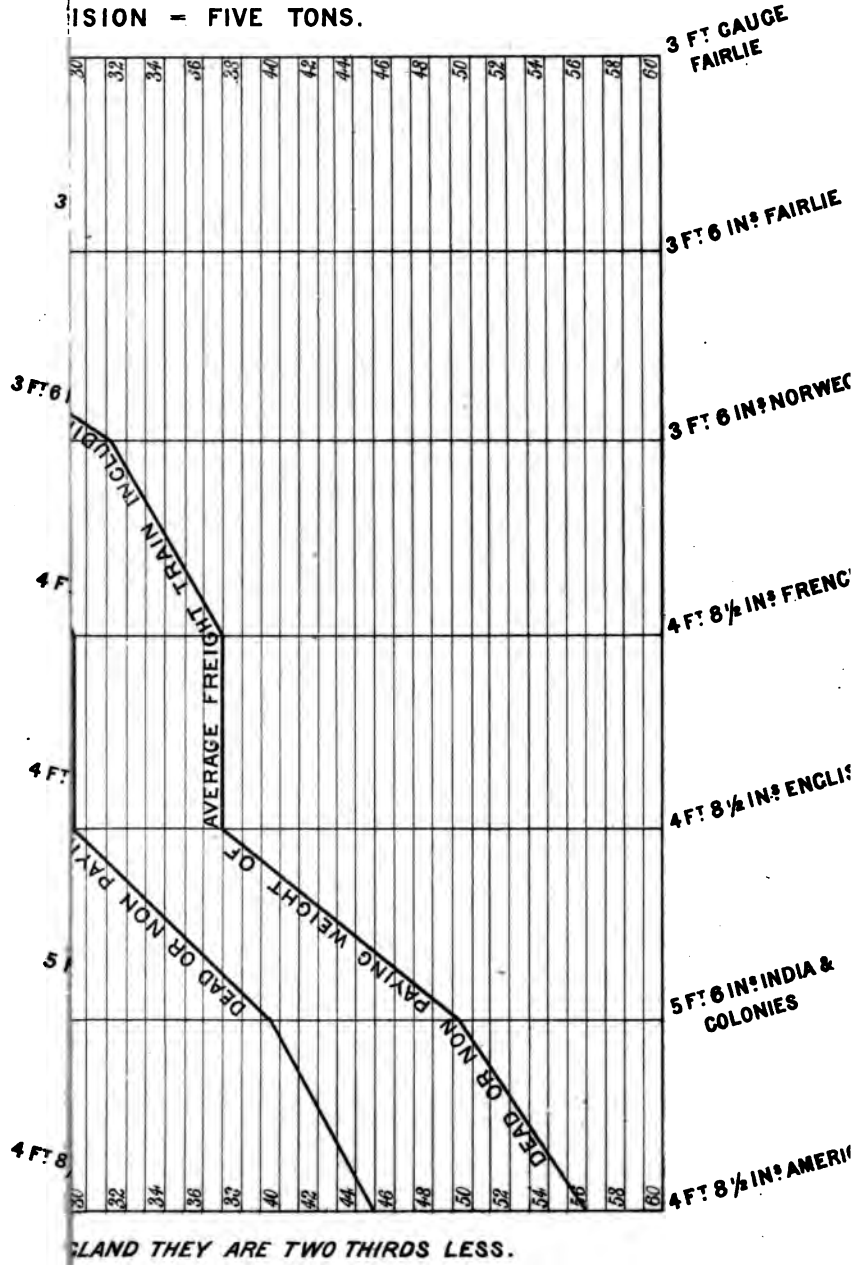
TABLE *showing the Numbers and Weights of Carriages required upon different Gauges, to carry any number of First and Second Class Passengers, from* 1 *to* 100 *in each Class, the Carriages being fully loaded.*

NUMBER OF PASSENGERS.	3 ft. 0 in. FAIRLIE.		3 ft. 6 in. FAIRLIE.		3 ft. 6 in. NORWEGIAN.		4 ft. 8½ in. FRENCH.		4 ft. 8½ in. ENGLISH.		5 ft. 6 in. INDIAN.		4 ft. 8½ in. AMERICAN.	
FIRST CLASS.	No. of Carriages.	Weight of Carriages.	No. of Carriages.	Weight of Carriages.	No. of Carriages.	Weight of Carriages.	No. of Carriages.	Weight of Carriages.	No. of Carriages.	Weight of Carriages.	No. of Carriages.	Weight of Carriages.	No. of Carriages.	Weight of Carriages.
		tons.		tons.		tons.		tons.		tons.		tons.		tons.
1 to 18	1	3·25	1	3·5	1	4·6	1	6	1	7	1	8	1	15
19 to 24	2	6·50	2	7·0	2	9·2	1	6	1	7	1	8	1	15
25 to 36	2	6·50	2	7·0	2	9·2	2	12	2	14	2	16	1	15
37 to 48	3	9·75	3	10·5	3	13·8	2	12	2	14	2	16	1	15
49 to 54	3	9·75	3	10·5	3	13·8	3	18	3	21	3	24	1	15
55 to 72	4	13·00	4	14·0	4	18·4	3	18	3	21	3	24	2	30
73 to 90	5	16·25	5	17·5	5	23·0	4	24	4	28	4	32	2	30
91 to 96	6	19·50	6	21·0	6	27·6	4	24	4	28	4	32	2	30
97 to 100	6	19·50	6	21·0	6	27·6	5	30	5	35	5	40	2	30
SECOND CLASS.														
1 to 30	1	3·25	1	3·5	1	4·6	1	6	1	7	1	8	1	15
31 to 40	2	6·50	2	7·0	2	9·2	1	6	1	7	1	8	1	15
41 to 60	2	6·50	2	7·0	2	9·2	2	12	2	14	2	16	2	30
61 to 80	3	9·75	3	10·5	3	13·8	2	12	2	14	2	16	2	30
81 to 90	3	9·75	3	10·5	3	13·8	3	18	3	21	3	24	2	30
91 to 100	4	13·00	4	14·0	4	18·4	3	18	3	21	3	24	2	30

ES AND AVERAGE
ND THE PAYING
T TRAINS.

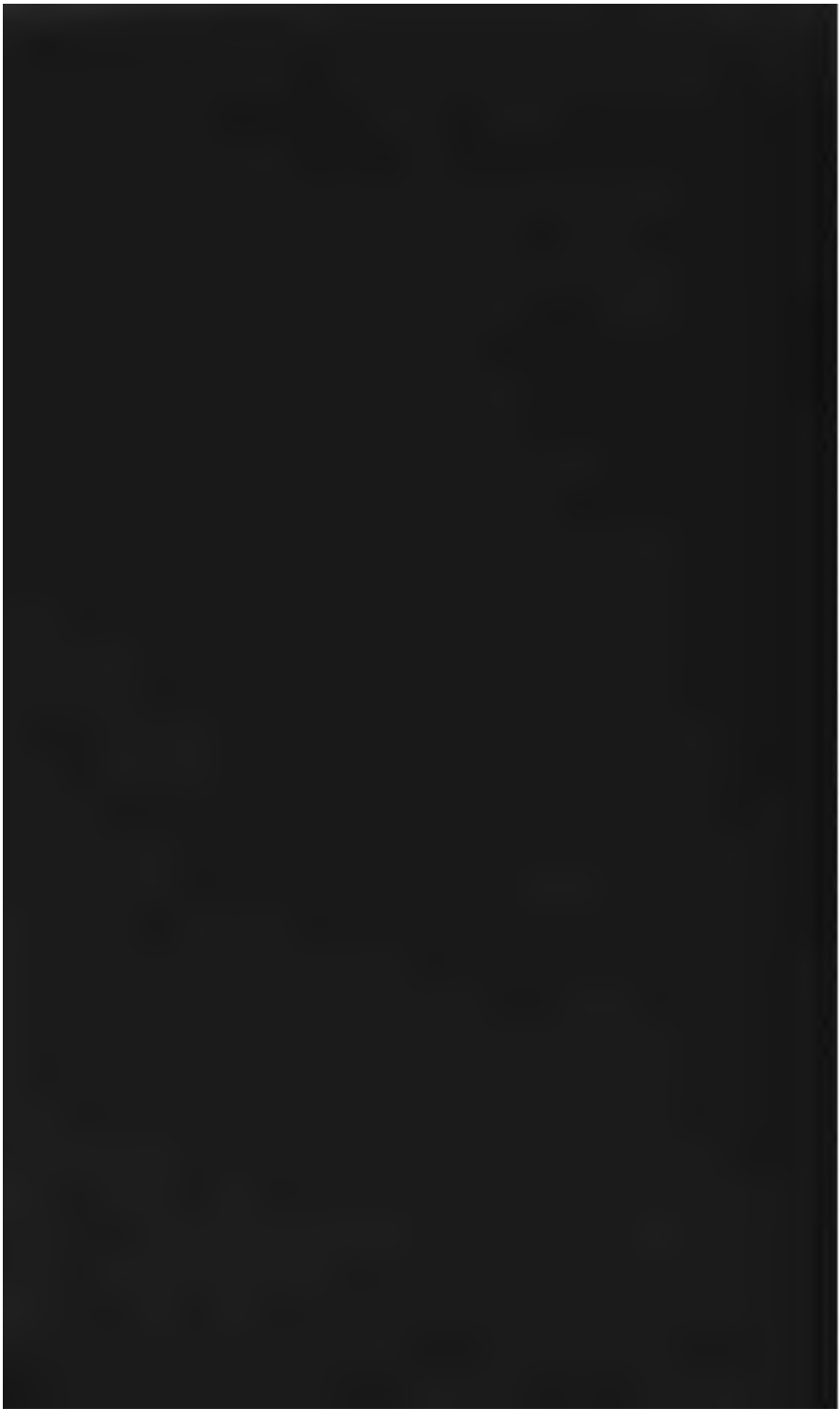
Nº 4.

ISION = FIVE TONS.


3 FT GAUGE FAIRLIE
3 FT 6 IN FAIRLIE
3 FT 6 IN NORWEG
4 FT 8½ IN FRENC
4 FT 8½ IN ENGLI
5 FT 6 IN INDIA & COLONIES
4 FT 8½ IN AMERI
AVERAGE FREIGHT TRAIN INCLUDI
DEAD OR NON PAYING WEIGHT OF
DEAD OR NON PAYI
30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60

GLAND THEY ARE TWO THIRDS LESS.

In Diagrams III. and IV. the dead weight, capacities, &c., of average wagon stock, and of an average freight train upon different gauges are compared, in a manner similar to that adopted with the carriage stock. The line of average paying loads is a very high one, being greatly in excess of that obtained either in English or American practice, and the same remark applies to the average paying weight of train—127 tons. In English practice the average paying load does not exceed 50 tons, so that although the load carried is less, the average load carried per vehicle is also so much less, that the gross weight of train would absolutely exceed that shown on the diagram—the proportion of dead weight being so much greater. It is needless to add that this excess would act upon each gauge in due proportion, although its effect would be much more felt on the broader than the narrower lines.

From the foregoing table and diagrams it will be seen at a glance how the dead weight is reduced upon the narrower gauges, and that only in a few combinations can the tonnage of the smaller carriages equal that of the larger ones.

THE END.